LLOYD'S REGISTER STAFF ASSOCIATION

TRANSACTIONS

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R. J. L. Ward.

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Lloyd's Register Staff Association.

TRANSACTIONS

FOR

SESSION 1935-1936.

LLOYD'S REGISTER OF SHIPPING,
71, Fenchurch Street,
London, E.C.3.

RULES.

(1) The name of the Association shall be "LLOYD'S REGISTER STAFF ASSOCIATION."

(2) The object of the Association is the advancement and dissemination of knowledge of present-day problems in Shipbuilding and Marine Engineering and Aircraft, by the preparation and discussion of communications on the various technical aspects of the subjects.

(3) The membership shall consist of the Technical Officers of Lloyd's Register of Shipping.

(4) The members of the Association shall elect Members of Committee and a President and Honorary Secretary who, in consultation with the Committee, shall arrange the procedure of the Association. All Past-Presidents of the Association shall be members of Committee *ex-officio*.

(5) The President, Honorary Secretary and Members of Committee shall retire annually and be eligible for re-election.

(6) Papers contributed to the Association shall be for the information of Members, and shall be available for the Committee of Lloyd's Register of Shipping, and the authors shall retain the right to subsequent publication, subject to the sanction of the Committee of Lloyd's Register of Shipping.

(7) Non-members may, at the discretion of the Committee, be invited to contribute papers to, or to discuss communications read before, the Association.

(8) Meetings shall be held during the first week of each month from October to April inclusive, and/or at such times as the Association may hereafter decide.

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"SHIPBUILDING AS A MEANS OF LIVELIHOOD."

By Sir JAMES LITHGOW, Bart.

Delivered 10th October, 1935.

Sir George Higgins.

Gentlemen, it is my duty to introduce to you the lecturer, but when we have a lecturer called Sir James Lithgow, one who is so widely known to you all, and, if he will allow me to say so, so very highly esteemed by you all, it is quite unnecessary for me to introduce him. We have had many lecturers here from time to time, but I do not think we have ever had a lecturer to whom we should wish to extend such a hearty welcome as to Sir James Lithgow.

The subject of Sir James' lecture tonight has caused me to think a little. It is "Shipbuilding as a means of livelihood." I have been for more years than I care either to remember or admit, a shipowner, and I have never for a moment supposed that shipbuilding was not a means of livelihood. I think I must have missed my vocation. I wish I had been a shipbuilder instead of a shipowner, and I do want to warn Sir James that anything he says to-night may be used in evidence against him the next time he comes to a shipowner in London and tries to make a contract. He must be very careful what he says about the livelihood the shipbuilders make. We all know it.

Now, I am not going to detain you, because you want to hear what Sir James is going to say, and I am sure we shall all receive his remarks with the greatest interest and regard.

Sir James Lithgow.

Sir James Lithgow, after preliminary and introductory observations, said:

The shipbuilding industry cannot be regarded merely from the point of view of the owner or manager of the shipyard. Shipbuilding to a country like ours is of importance, indirectly and directly, to the whole nation, and I would like you to regard my remarks rather from that point of view than from any desire to give you hints as to how you can make a profit out of building a ship.

From the larger national standpoint I think we can claim, for the present generation certainly, that thinking people in our country to-day are agreed that the justification for the existence of the individual citizen is the service which he renders to those around him. I am far from suggesting that such service must necessarily be voluntary public service, or even public service of any kind. On the contrary, I believe that the service the individual renders in the course of his normal avocation —by which he obtains his means of livelihood—is really the measure by which the usefulness of

the great majority of us can be judged. I have, therefore, ventured to attempt to direct your thoughts along the line of what service is being rendered to our Empire by those who are engaged in the multifarious duties which constitute the vast and complex industry of shipbuilding.

Service is indeed a tradition of Lloyd's Register, whether it is exercised by membership of the voluntary Committees, or by the salaried staff. The records of the learned Societies are rich in contributions from the staff, and those of us who came into contact with its surveyors know that it is not merely in the service of the Committee which provides their salary, but also in the service of the individual shipowner who calls for their supervision, and the individual contractor who calls for their advice, that they discharge their duties and exercise their technical ability.

When one contemplates a complete ship, whether it be a "QUEEN MARY" or a humble coasting tramp, one is at once struck by the vast diversity of scientific knowledge, designing skill and craftsmanship which goes to make the finished whole. The individual who serves the community through following the shipbuilding industry has every reason to be proud of the fact that he earns his bread in an honourable calling.

Shipbuilding can hardly be described as a basic industry in the sense of producing primary products —such as agriculture, mining or even iron and steel, but to a country like ours it is a fundamental key industry, shaping and assembling some of the products of almost every branch of our industrial life and fashioning them into means of transport and defence which constitute the very life of our empire.

In these days, when our export trade is in the doldrums, it seems to me even more important that we should realise how fundamental our shipbuilding industry is to almost every trade in the country. When you consider that anything from nails to cotton sheets, blankets and all such things, as well as the articles which one usually associates with a ship, are incorporated in large quantities in the complicated modern vessel, one realises the importance which the shipbuilding industry, fully developed, bears for every trade and every profession in the country.

On the carrying side, as you know, a great deal has been said and written in recent years about welding the Empire together and developing Empire trade, since the foreigners are less inclined to deal with us than before. From that point of view also it is necessary to remember that the ability of our shipbuilding industry to turn out the very best ships under the best conditions is again fundamental to the proper development of our whole empire.

Turning for a moment to the more technical side of the industry we find that by its nature it is also, I venture to believe, of very great importance to our national well-being. There is little of a mass-production nature about our industry. Few of those who gain their livelihood from it can do so without the exercise of study, skill or strenuous labour. We are all accustomed to look upon sea-faring nations as necessarily vigorous and hardy by reason of their calling, but it may be fairly claimed that a nation in which the shipbuilding industry is firmly established is no nation of automatons, but a people keen of brain and dexterous of hand. There can be little doubt that the scope which the shipbuilding industry has given our countrymen to develop these characteristics has left its mark on the character of our people, and that any circumstances which tend to diminish the importance of the shipbuilding industry in our national life will not only paralyse and weaken innumerable other industries dependent upon it, but will sap our vitality as a progressive industrial people. The distress and depression and tendency to despair which have accompanied the contraction of our staple industry on the Clyde and Tyne, are warnings of the effect upon the whole nation if we lost this important section of our commercial activity.

I believe the shipbuilding industry gives a unique outlet for the exercise of those qualities which are necessary for a progressive, powerful, industrial nation, and the development of those qualities for which the shipbuilding industry gives scope, has a very definite repercussion on our ability to organise and develop other kindred industries.

We have been talking of this matter as a means of livelihood, and it is obvious that no trade or calling can be carried on merely for sentimental reasons. Those engaged in it are entitled to draw from it a means of livelihood on a scale of living comparable with that enjoyed by their fellow countrymen in other walks of life, and this applies not only to the working man, not only to the owner of the shipyard, who has passed through a trying time of misfortune, but to all those others, particularly I should say the

technicians, scientists and designers, who concentrate on the problems of this industry. It seems to be quite obvious that the rewards that the industry has held out for the exercise of scientific and mental ability have not been commensurate or comparable with those which other industries have been able to hold out in recent years. This has certainly not only had a most discouraging effect on many skilful persons in these lines, but I am afraid it has discouraged some who would have been assets to the industry, but who have gone into other industries to the loss of our own, and it may well be to the loss of the country as a whole as time goes on.

I would, however, put in a definite and, shall we say, blatant plea that it is obvious that those who provide the capital necessary to develop new ideas must be assured of a return commensurate with the risks they run if the industry is to be equipped to play its part in these strenuous times. There has been a tendency in recent times to look upon the making of a profit as something to be ashamed of. That is not my idea. The person who carries on his business without making a profit I consider a fool, as he cannot continue to discharge his obligations for any length of time on that basis. Further, any business must be in a position to provide every one of those engaged in it with a reasonable means of livelihood, and that is the position which used to be the case in shipbuilding, and which I trust will be the case again, but which for the moment is certainly not the case. I might give one illustration of the kind of thing which the absence of proper remuneration creates.

You are aware that in the olden days my firm and other firms similarly situated used, as a matter of course, when they could not get an order owing to depression, to put down vessels "on spec." They did not do that for fun, but thought that it would ultimately be profitable, and the effect was beneficial for the districts in which they had their works and for the whole industry, because it evened out the ups and downs which were inevitable to anyone dependent on the ebb and flow of world trade. That was the fulfilment of an obligation on the part of those who had made money out of the business to keep their money in the business without undue risks to themselves. The plain fact of the matter is, however, that conditions in the last few years have made it impossible for that type of business to be carried on, and the result has been to accentuate the depression which was coming anyhow. I do not claim for my fellow shipbuilders that we had any special monopoly of that wise public spirit. There were many shipowners in the same position, but they are now scarce for the same reason. I give that example to show how important it is for the smooth running of an industry that those who run it should be able to discharge their duties to the industry.

I think every good citizen to-day realises he has an obligation to his country in the course of his ordinary commercial business, perhaps in even a greater degree than used to be realised in past generations. I have explained in some detail the fact that this industry I am speaking about is a very complex one, and I would like again to come back to the definition of a shipbuilder. I did not say "shipbuilder" in my title. I referred to "shipbuilding," but naturally one associates the shipbuilder with shipbuilding, and those of you who know about the business realise that nowadays it is perfectly impossible for any one individual to be expert in the vast number of things which the complete shipbuilder ought to know.

I have referred to the developments of science. Naturally the shipbuilding industry must have in its ranks men of science or people of that turn of mind. On the other side you have got to have people with practical mechanical knowledge. Again, you have got to have people with the aptitude and the experience for buying and selling—commercial aptitude. Then you must have others in the industry who have a flair for the judgment of men and an appreciation of what are fair and reasonable labour conditions. Then, in the wider sense, you must have judgment as to what is likely to be the future in world affairs, and above all in the end all these qualities combined must bring forcibly to the front that economy in cost is all important in a world-wide industry and in a strenuous competitive industry like our own.

It is perfectly obvious these different qualities cannot be found in one individual. Many are completely opposite, and those that are expert in one are perfect duffers in another and so the shipbuilder, to be really worthy of that high-sounding title, has to be a team worker—the guide of a team or the loyal member of a team. That is a thought which should hearten every one of us in the industry, that we are practising a trade where co-operative action and team work is essential, and there is nothing better to develop character than an early appreciation of these important matters.

Perhaps in passing I may suggest that in the consideration of training for those who are entering the shipbuilding industry, while it is necessary in later life to specialize in one thing or the other, it does seem to

me that the educational approach to an industry such as ours might be rather wider than it is in certain instances at the present time. To be a scientific naval architect does not mean that you are an all-round shipbuilder, but if the educational authorities can devise a means whereby the budding shipbuilder gets an opportunity of dabbling in the various branches he may have a wider opportunity of shining when he gets on and not find himself too much in a particular groove.

Talking of leadership and the organisation of the shipbuilding industry, of course we shipbuilders are a proud lot and inclined to be conceited, but I do believe that the nation as a whole realises that the shipbuilding industry has profited by this time of slackness to improve its efficiency. You know that at one time even this Institution was thought to be a bit behind the times and played unduly for safety and did not appreciate the advances which had come about: I well remember, even in my comparatively short life, two separate occasions on which Lloyd's Register has looked into things with the result that the efficiency of the cargo ship (I am speaking particularly of the cargo ship as a money-making proposition) was greatly improved.

We owners of shipyards have been trying to "rationalize" ourselves, as the expression goes. Of course, we get a lot of abuse for the selfish motives which are supposed to be uppermost in our minds, but the fact is that we have done a considerable amount of cutting out of deadwood, which is of no use in an industry, and we do believe that shipbuilders have played a worthy part, whether in the scientific section or in the practical organising section, or in the management of the shipyard. We do believe that, in spite of stories we hear of the wonderful things done in other countries, this country realises we have done our best and are worthy of the best the country can do for us. It is clear that if the country wishes the industry to play its part, and a very important part it can be, in the development of the empire, it must pay us some little more attention than it has done in the past.

We, unfortunately, are not the only country which realises the importance of a healthy shipbuilding industry. International progress and world-wide development made competition from other countries inevitable, but what rather worries us, those of us who have to depend on the ultimate result of the profitableness of our work, is that, on the one hand we have, through the country's policy, certain self-imposed disabilities placed upon us, and on the other hand we find that our competitors, far from being the Cinderellas of their country's industries, are singled out for special treatment in regard to subsidies and so forth.

Obviously the problem is full of complications. The greatest complication is that a country whose shipbuilding industry is comparatively small can afford to be generous without breaking anyone's heart. Where the shipbuilding industry is a large one, this generosity today involves national sacrifice on a much larger scale, and one knows we have suffered very badly from a most praiseworthy desire to limit defensive armaments. This has removed the means of livelihood from a large section of our nation. It would seem that this has been carried too far. Far be it from me to be wise after the event, but I cannot help thinking that what has been done in that line was the right thing, and the sacrifices entailed upon the shipbuilding industry were justified under the circumstances, but that does not necessarily mean that any of us can look with equanimity on a continuance of that policy. On the contrary I think it has proved entirely unproductive, and we shipbuilders have no hesitation in saying the policy must be reversed, not only because of national safety, but because we feel a serious call on our industry for defensive purposes would be the best possible means of reproducing health in the whole body. We look, therefore, to some improvement on the naval side, and the possibility of developments that will undoubtedly be beneficial throughout the whole area of the industry.

I have indicated that some of our troubles were self-imposed. Well, of course, that thorny subject is an unpopular one, but it is well known that for many years now there have existed two types of industry—the sheltered and the un-sheltered. Why certain sheltered industries should be selected for the gifts of subsidies and others should be left out has passed my comprehension. You know that a man whom in Scotland we call a "joiner," has entirely different conditions when he is building a house than when he is working on a ship. While working on the house he receives a subsidy, but when working on the ship he receives none. While it is desirable everybody should have a suitable house, it beats me why they should get a comfortable house at the expense of the taxpayer, and why the man who builds a house should have special conditions. That the shipbuilder does not get these special conditions does not seem to me to be logical, and for a maritime nation it does not seem to be just.

What I am leading up to is that as an industry the nation is indebted to us. We have sat back and seen our opportunity for building defensive ships denied us, and we hope that the lee-way will be made up. We have looked on and seen money expended on all kinds of things to keep our people fit, but one wonders what they will be fit for if one of our principal industries—shipbuilding—is to be allowed to die away. I do say quite definitely that the nation owes a debt to the shipbuilding industry that they have got to bestir themselves to pay.

I do not wish to be out of place by discussing ways and means now. As a matter of fact it would be out of place for me to raise it at all had it not already been taken up in high quarters, and I think it is one of the elements of the present policy that the shipping and shipbuilding industries should be assisted. I do not wish to make any suggestions as to how it is to be assisted, but I merely desire to emphasise that, if it is to constitute the means of livelihood of a large body of our people, it should be assisted as much as other industries which are supposed to be of national importance, such as the building of houses.

I have referred to the number of people engaged in the industry, and I do not wish to hold out any foolish hope that our industry can obtain the proportion of world business it used to do. I am afraid we have got to face the fact, and we have suffered from it, that certain sources of business are no longer open to us. Perhaps that is no reason for discouragement. It was inevitable, but what we have got to do is to consolidate the position as best we can, and we look to the situation being faced fairly by the British public.

Most of you are in the industry already, and I feel rather like the minister who chided his congregation for not turning up, whereas those to whom his remarks were really addressed were not present. But you are interested in the industry, and you have influence outside the industry, and I do think you would be doing a great service to the country if you make your views more and more felt that the shipbuilding industry is actually in a serious state, and that it is the concern of the country rather than of the comparatively few who happen to be in it at the present time.

For my part I refuse to believe the British public will allow the pursuit of any particular political policy to bring about the collapse of the shipbuilding industry. They have imposed serious handicaps upon us, and they have run risks with the best intentions in the cause of peace and for lack of any known ideas of combating the question of foreign competition ; but Britain owes her place as a great power to the fact that her people are imbued with the spirit of enterprise, and those who run the risks of enterprise are the ones who should reap a just reward.

Whatever may be said to the contrary, the British people as a whole realise the justice of that way of looking at things, and I feel certain that the difficulties that we are meeting with will be fairly faced by them, and that means will found, not to bring us back to the old scale where we were providers for the shipping of the world, but to some reasonable basis which will afford a means of livelihood to those engaged in it, and attract a larger number of the coming generation than seems to be possible at the present moment.

My firm conviction, as well as my fervent hope, is that the nation will realise that the provision of a decent livelihood to all those in the shipping community is one of their first obligations if they desire Great Britain and Ireland to prosper, and if they have any idea of reality in the suggestion that the British Empire is to be knit together and go forward as a great power holding the great traditions of the British race such as we have established it in the past.

Mr. W. Watt, a past president of the Association, who served his time as an apprentice with Messrs. Russell & Co., proposed a vote of thanks to Sir James Lithgow and gave some interesting details of his early experience with the firm and association with the lecturer.

It was about that time that Sir James, then a young man, in association with his brother, Mr. Henry Lithgow, assumed the direction of the firm.

Mr. Watt said that under no compulsion of circumstance to adhere to shipbuilding as a means of livelihood, they decided to devote their very considerable energy and ability to the further development of their shipbuilding interests—no light undertaking.

It was a fair contention that they, conjunctly with others who undertook similar heavy responsibilities and risks, rendered great and valuable service to the community and the nation.

Mr. R. J. L. Ward, in seconding the vote of thanks, referred to his connection, from 1906 to 1909, with the Kingston Shipyard, Port Glasgow, one of the most productive shipyards in the world.

Sir James Lithgow—Mr. Chairman, Mr. Watt and Mr. Ward. It is extremely kind of you to say these nice things about me, and it is good of you, gentlemen, to respond so enthusiastically.

Mr. Ward I look upon as a colleague. We were together in the drawing office, and it is a gratification to me to feel that both Mr. Watt and Mr. Ward, who held responsible positions at Russell's, have now assumed wider and greater responsibilities in Lloyd's Register.

Last night I was reading an article before I sat down to prepare finally for this talk. The writer was ridiculing the idea of the 4-hour day, and he indicated that the keynote of happiness was really to take an interest in your work, and that, I may say, has been my philosophy. Whatever I have had to do it has been my luck to have had jobs I was interested in and have enjoyed doing, and I do not think anyone who does not appreciate his work, but merely looks upon it as a means of livelihood, can give of his best, whoever he may be. I am sure the best way of achieving happiness is to be really interested in our work, and that is what we have all tried to do both in Lloyd's Register and the shipbuilding yards.

The meeting was brought to a conclusion by Mr. E. W. Blocksidge, the President, who expressed the thanks of the members to Sir George Higgins for his continued interest in the Association and for taking the Chair on this occasion.

SOME EARLY MARINE ENGINEERING EXPERIENCES AND PRACTICE.

By Engineer Captain EDGAR C. SMITH, o.b.e., r.n.

Read 7th November, 1935.

In beginning my lecture, I should like to express my appreciation of the honour conferred upon me by being asked to lecture before the Staff Association of this world-famous Institution. To the man in the street, Lloyd's Register may mean little, but to all those connected with shipping, shipbuilding and marine engineering, the name signifies all that is excellent. The term A1, which you use in your classification, has long become a common but significant expression by multitudes who know little of its origin, but to lecture before a body which is constantly occupied with things that are A1 is no mean task ; but while I ask for your indulgence I feel that no audience in the world is more likely to be interested in marine engineering history than the present one, and though I may not qualify for your highest classification I trust that what I have to say will increase your interest in the instructive and entertaining records of the past. Many of the things we regard as modern were thought of quite a long time ago, and it was only the backward state of engineering which prevented them being utilised.

I take it for granted that you all know that the first experimental steamboats appeared almost simultaneously in France, America and Great Britain about a hundred and fifty years ago and that it was with Fulton's "Clermont" of 1807 and Bell's "Comet" of 1812 steam navigation as a regular means of transport had its birth in the new world and the old world respectively. There were many projectors of steamboats and still more critics of them. The scepticism which prevailed need not surprise us for the difficulties were tremendous and the failures very numerous. But from the days of Fulton and Bell there has been no break in the line of progress. To this progress hundreds of original, ingenious and persevering men have contributed. The names of some of these have become household words, but the names of others have long since been forgotten. But whether they gained fame and wealth or whether they sank into poverty and obscurity these men are all our benefactors and to them we owe the foundation of the great marine engineering industry.

There is no need for me to point out that the history of marine engineering practice covers a very wide field. Some of it is to be found recorded in text books, the transactions of societies, technical journals and magazines, official regulations and in the reports of Government Committees. The last of these sources is one of the most fruitful and it is from a report of 1822 that we get a glimpse of the state of marine engineering ten years after Bell had launched the "Comet" and when there were about 150 steam boats plying on our rivers and around our coasts.

The report I refer to is that of the Holyhead Roads Committee which was appointed by the House of Commons in connection with the Post Office Steam Packet Service. Though at that time neither the Menai Straits Bridge nor the Conway Bridge had been built, the important road from London to Holyhead was being reconstructed by Telford and the Post Office had placed two steam vessels on the run between Holyhead and Dublin. The previous year the Post Office had begun sending the mails to France by steam vessels and the matter was regarded as one of growing importance. The vessels sailing between Wales and Ireland were the "Royal Sovereign," 205 tons, 80 horse power, and the "Meteor," 190 tons, 60 horse power, both of which had been built at Limehouse and engined by Boulton and Watt. The Committee was required to report on the proper construction of boats for such work, the organisation of the mail service, the staffing of the vessels, their navigation at sea, the types of boilers and engines most suitable for the purpose and their preservation in good working condition.

Presided over by Sir Henry Parnell (afterwards Lord Congleton), the Committee met at intervals during the months March to June, 1822, and examined individuals connected with the mail services, captains of vessels and also many of the best known engineers among whom were Joshua Field, Timothy Bramah, Bryan Donkin, Marc Brunel, David Napier, James Brown, Charles Wye Williams, Jacob Perkins and William Brunton, while one important witness was Michael Faraday. The boilers used at that time were of the box type with flues, working at a pressure of 5 lbs. per sq. in. or less and the engines were usually, though not always, of the side lever type. Most of the witnesses agreed that the machinery of steamboats should be much stronger than land engines and some thought it was well to have one part, say the crosshead, weak enough to break in case the engine was brought up suddenly. The side levers, connecting rods, crossheads and even crankshafts, were of cast iron, for there was still some difficulty in making large wrought iron forgings. As to the engine in general, James Brown, of Boulton and Watt's, when asked "In case of constructing a new engine for a Holyhead packet, can you suggest any improvements?" replied, "Merely in respect to making the materials stronger and heavier. I conceive the construction of the engine is almost incapable of improvement as it now is." On the other hand, Brunel thought various improvements could be made, the engine, he said, "is now, as it were, a gigantic untamed animal, which has to go through rocky and uneven ground, dragging by main force its load; or rather an unwieldy truck with small wheels and large axle trees."

One communication to the Committee was from Jacob Perkins—a great pioneer in the use of high pressure steam—who wrote from 69, Fleet Street referring to the high pressure non-condensing engines used in America. "High pressure engines, built on Oliver Evans' plan," he wrote, "are known to be *perfectly safe*, owing to their peculiar construction. The boiler, which is considered to be the only dangerous part of a steam engine, when made on Oliver Evans' system never explodes. The boiler consists of a cylinder made of wrought sheet iron of $\frac{5}{16}$ths of an inch in thickness, its diameter is 30 inches and its length 18 feet. . . . As each end of the cylinder a disc of cast iron of four inches in thickness, is so firmly secured, that the wrought iron part of the boiler would give way with a quarter part of the power necessary to explode the cast iron ends. When the boiler gives way, which must necessarily be the case sooner or later, it will be at the weakest part. The rend or opening, which takes place when the boiler gives way to relieve itself, discharges no more steam than is usual for the safety valve to emit. . . . An account of upwards of 600 of these rends have been recorded without the slightest injurious effect having been produced. . . . The boilers (when from long use they give way) are readily repaired in the following simple and easy manner: After the boiler is cooled down . . . a workman enters the main hole with a patch of lead (which is always kept ready for the purpose) and secures it immediately over the rend with a wooden brace. The pressure of the steam will close this patch of lead and make the boiler as tight as before. I have known this temporary remedy stand for months."

On "Lunœ 13° die Maij" and on "Sabbati 1° die Junij," 1822, as the report records, Faraday was a witness, and this is probably the first instance of an eminent chemist being called in to give advice on a marine engineering matter. In the course of his examination Faraday gave analyses of sea water, referred to the various salts it contained, stated the conditions which must be present for the various salts to be deposited, and explained how corrosion was set up. In a long communication dated "Royal Institution, May 7th, 1822," Faraday, referring to the means by which the engineer could determine the specific gravity of the water in the boiler, wrote: "I think the best instrument the man could have would be the hydrometer with one, or at most two marks upon it, the one to indicate the density of the

water when it begins to deposit common salt, and the other the density, perhaps, when it begins to deposit sulphate of lime. Regard must of course be had to the temperature, but that is a point easily arranged." Faraday also suggested the use of lime, potash or soda for neutralising the acidity of the boiler water, and the fitting of horizontal iron tubes in the bunkers for taking the temperature of the coal. Many curious questions were asked the various witnesses, but none perhaps more surprising than the question put to Faraday "Would a dry holly or thorn bush introduced, if practicable, into the boiler take off a part of the crystallization which would otherwise adhere to the bottom of the boiler." Such are some of the views and opinions contained in the Holyhead Roads Committee Report, a perusal of which affords much food for thought and not a little entertainment.

The majority of the boilers used in the early days of steam navigation were great box-like structures, with square furnaces and rectangular passage-like flues. For their power they were very heavy, and contained large volumes of water. Sketches of many boilers are to be found in the old text books, but Slide 1, showing a boiler made by Maudslay, Sons & Field for H.M.S. "Comet," will serve to give a good idea of a typical marine boiler of a hundred years ago. Most boilers were made of wrought iron, but these were made of copper. A copper boiler would outlast three iron boilers and it then had a considerable value as scrap. It must be remembered that when such boilers were made the size of individual plates was quite small, and there was an immense amount of riveting in a boiler, and, as the workmanship was none too good, there was a good deal of leakage. Indeed, John Dinnen, the first naval engineer to attain the rank of Inspector of Machinery, writing in 1838, said that when water was first admitted to an iron boiler there were hundreds of leaks, only the worst of which would be stopped mechanically, the remainder were left to rust up. All sorts of substances were used to help stop the leakage, and it is on record that when some new boilers were being tested at Woolwich it was directed that two sacks of oatmeal should be scattered about the water spaces. In the "Comet's" boiler it will be seen that there are two sections, one containing the furnaces and one the flues, the two being joined together by a "smoke ring." The flues were just sufficiently wide and high enough for a man to enter, and seeing the circuit of the gases was a long one the task of the stokers who occasionally had to squirm their way along the flues to remove the soot was certainly not one to be envied. The boiler bottom was flat and the boiler rested on a wooden platform, over which was spread mastic cement consisting of powdered glass and stone, sand, litharge, grey oxide of lead and oil, which hardened quickly. It was not an unknown thing for a boiler to be used with parts of the bottom plating corroded through. It is interesting to note that when boilers were used with very low pressures, the pressure on the bottom due to the head of water was greater than that due to the pressure of the steam. The usual pressure a hundred years ago did not exceed 5 lb. per square inch and 15 lbs. pressure was spoken of as "high pressure."

Then, as now, the bugbears of the Marine Engineer were corrosion and scale. With vessels plying on the rivers and using comparatively fresh water it was easy to keep boilers fairly clean, but when they made longer voyages at sea the question of salt often led to serious trouble. In early naval steam vessels it was the practice when at sea to let down steam every third or fourth day, empty the boilers and refill with fresh sea water. This procedure was followed by blowing down every two hours. With the low pressures in use intelligent engineers could by this means keep their boilers remarkably clean, but it was not an unknown thing for a steam mail packet to arrive back at Falmouth from a voyage to the Mediterranean with her water spaces between the flues almost choked with salt. One way of loosening the salt on the plates was to light a fire of wood in the furnace when the boiler was empty and cold, and so try and crack off the scale. As early as 1838 Dinnen remarked "nothing but the use of distilled water will ever thoroughly obviate the evils to which marine boilers are subject on very long voyages." It may be of interest to recall that the "Kingston" valves fitted on a ship's bottom, through which the boiler water was ejected when a boiler was blown down was due to a foreman of that name at Portsmouth, who invented the valve.

The fittings on the boilers included one or more safety valves, a water indicator, a U tube pressure gauge, and a reverse or vacuum valve. Though spring loaded safety valves were in use on locomotives, marine engineers clung to deadweight safety valves until the seventies of last century. They were troublesome things in those days, and were sometimes tampered with. Captain Chapple, R.N., Superintendent of the Steam Packet Service between Great Britain and Ireland, when writing about the undesirability of steam boats racing with one another, said "This cannot be too severely prohibited,

particularly if there only be one safety valve and that accessible. I have known an instance in a private steamer of the engineer standing on the safety valve to increase its weight, nor could he be induced to remove till one of the passengers threatened to knock him off with a hand-spike." The water-level gauge was a ball float with a pointer outside the boiler, and this was preferred by some long after water gauge glasses were introduced.

The pressure gauge was a U tube partly filled with mercury. On the mercury was a float with a marked rod. If an engineer wished to deceive anybody about the pressure it was easy to lift out the float and put a piece of cork underneath it. Some engineers liked the U tube pressure gauge because on occasion it would act as a small safety valve. Safety valves, water gauges and pressure gauges survive to-day, but you will look in vain for a reverse valve. The old box boilers were so weak that it was necessary to prevent a vacuum forming inside as the boiler cooled down, so every boiler was fitted with a valve which opened inwards when the pressure inside the boiler fell a little below the pressure of the atmosphere.

The most popular type of marine engine in the early days was the side lever engine shown in section in Slide 2. This was more or less an adaptation of the Watt beam engine, with two beams at the sides instead of one overhead. The cylinders were sometimes jacketed, and I believe the introduction of cylinder relief valves was due to Maudslays. Pistons were packed with hempen gasket, and a good deal of tallow was used on the engines, both externally and internally. Two side rods connected the crosshead with the beams and some form of parallel motion was used for keeping the piston rod in line. In the Navy the first engineer had to know how to keep the parallel motion in order, but no such extensive knowledge was required of the second engineer. The old text books contain diagrams of the various parallel motions and instructions for calculating the lengths of the various rods. Long D slides were used, driven by a single eccentric. The eccentric sheave rode loose on the shaft, it was balanced and there were stops on the sheave and crank shaft for going ahead and astern. On starting, however, the slide valve had to be moved up and down by hand by means of a long lever. All engines had jet condensers, and the air pump served the combined purpose of circulating pump, air pump and feed pump. Opening and closing the injection valves on starting and stopping was a very important duty, and it was a simple enough mistake to completely flood the engine with salt water. On starting it was absolutely necessary to first form a vacuum in the condenser. This was done by flooding the engine with steam until the steam was seen coming from the snifting valve. This having been done, the injection water was turned on, a partial vacuum was formed and the engine could then be moved. In some vessels the air pump discharged a part of the injection water and condensate into a tank placed sufficiently high for the boilers to be fed by gravity. Some of the details of both boilers and engines are shown on Slide 3, while Slides 4, 5, 6, 7, 8 and 9 are illustrations of other paddle engines. Slide 4 showing Seaward's direct-acting or "Gorgon" engine; Slides 5 and 6 Maudslay's "Siamese" engine; Slide 7 the very fine oscillating cylinder engines of the "Great Eastern," while Slides 8 and 9 are other illustrations of side lever engines.

Though most of the practice I have referred to was followed generally, there were numerous inventors and projectors with quite sound ideas on such things as tubular boilers, water tube boilers, high pressure steam, surface condensers, and also the use of screw propellers instead of paddle wheels. As we all know, however, it takes a considerable time for a new idea to gain widespread support, and an example of what may happen to a capital improvement when brought forward under unfavourable circumstances is that of the marine surface condenser, as introduced by Samuel Hall. Distillation and condensation are very, very old processes, and are bound up with the earliest history of chemistry. Who was the first to condense vapour in a closed vessel and so obtain a vacuum, no one can say, but we do know that the principle was incorporated in all the engines of Savery, Newcomen and Watt. In a Newcomen engine, the cylinder was both a steam cylinder and a jet condenser, and to Watt we owe the important improvement of the use of a separate vessel for condensing the steam, and an air pump for removing both the condensate and the uncondensed vapour. To Watt's prolific ingenuity we also owe the tubular surface condenser, which however, he never applied. After Watt, Cartwright, David Napier, John Ericsson and others had ideas on condensers, but the marine condenser as we know it, is essentially the child of Samuel Hall, and one of his patents—No. 6556 of February 13th, 1834—stands as a landmark in marine engineering history. This patent was for a five-fold combination—a tubular surface condenser,

a circulating pump, an air pump, a still or evaporator and a "steam saver." The construction of his condenser, his evaporator and steam saver—a form of automatic silent blow-off—are shown in Slide 9. The first vessel Hall's arrangement was fitted in was the "Windermere," the engines of which were made by Fawcett Preston & Co., of Liverpool. In the *Mechanics' Magazine* of September 12th, 1835, is a letter dated August 19th, 1835, to Hall from George Peel of the old firm of Peel, Williams and Peel, of Manchester, which ran as follows :—

> "I yesterday witnessed with much satisfaction, the performance of a pair of steam engines, fitted up with your recent improvements on board the "Windermere." The engines were working well without anything like effort, thirty revolutions per minute, and although the vacuum was impaired in consequence of a defective joint, yet the barometer attached to the condenser indicated the rise of a column of mercury equal to $28\frac{1}{4}$ inches ; the ordinary barometer standing at the same time at 30·2 inches."

Other vessels fitted with Hall's condensers were the "Wilberforce," "India," "Queen," "Sirius," "British Queen," HMS "Megaera" and HMS "Penelope," and Hall's apparatus proved eminently successful when properly used, yet for all that, in a very few years the plan of Hall was abandoned and not till the eighteen-sixties did the surface condenser make real headway.

The objections to Hall's condensers were that they were unnecessary and expensive and that they soon became clogged with grease. As boilers lasted longer with Hall's condensers, one writer said "It is easy to assign a reason for this opposition ; the trade in boilers would be spoiled, as only one-third the quantity would be required for marine purposes." The real objection, I think, was the grease. A great deal of oil and tallow was used in the cylinders, and in a statement of the relative merits of the jet condensing and surface condensing engines it was said that "In injection engines the oil which is put into the cylinders, stuffing boxes, slides, etc., is speedily carried away by the injection water into the sea," while in "the patent engines, not a particle of the oil which is given to the internal parts of the engine, etc., is wasted away into the sea, or lost, but it is all carried into the boilers, whereby they are protected from corrosion, and an ample lubrication of the engine is effected at scarcely any cost . . ." The claims for the "patent engines" were generally well founded, but it does not seem to have occurred to the writer of the statement that much of the grease was bound to be deposited in the condensers as it actually was. Hall, who was born in Nottinghamshire, in 1781, the same year as George Stephenson, deserved well of his contemporaries but when he died in Bow, in the East of London, in 1863, he was in very reduced circumstances. He is one of those who should be remembered by all those who go down to the sea in ships.

Perhaps the most interesting chapter in early marine engineering history is that relating to screw propulsion. There were scores of patents relating to screw propulsion and the ideas of how a screw for a ship should be made, where it should be placed, and how it was to be driven, do credit to the fertility of the human mind. Like other innovations the screw brought in its train several difficult problems. In the first place the screw shaft had to revolve much faster than a paddle shaft, and it was essentially the day of low speeds of revolution. Secondly, there was the problem of where and how to take the thrust of the propeller shaft, and in old note books you come across such terms as "pushing bearings" and "pushing posts," and, thirdly, there was the design of the bearing where the wrought iron stern shaft passed through the stern post. Some of the succeeding slides will show you how these difficulties were overcome. The stern tube bearing was perhaps the most difficult problem of all, and so long as marine engineers clung to brass bearings there was always trouble, and this trouble had much to do with some shipowners preferring to stick to paddle wheels. It was John Penn, of Greenwich, who introduced the lignum vitæ bush, and a record of his experiments are to be found in two papers contributed to the Institution of Mechanical Engineers in 1854 and 1856 respectively. Just when his experiments were being made the famous "Great Eastern" was being laid down. As you know she was driven by both paddle wheels and a screw.

Whether there is in existence an account of the details of her machinery with sketches I do not know, but through the kindness of Mr. Charles de Grave Sells I have been able to read a report written by Joshua Field, after he and John Penn had been asked to examine certain features of her machinery. The report is dated March 15th, 1860, i.e., two years after the vessel was launched, and from it I have

extracted those portions which relate to the thrust bearing. Some particulars of the ship were given by the late Mr. Charles H. Jordan in his Historical Records and Reminiscences, contributed to your transactions in June, 1925, and I think that this report will be found a valuable addition to what Mr. Jordan wrote. Whether the alterations to her stern tube, as suggested by Field and Penn in March, 1860, were made before her maiden voyage to New York, in June, 1860, I do not know, but it is quite evident that it was asking for trouble if they were not.

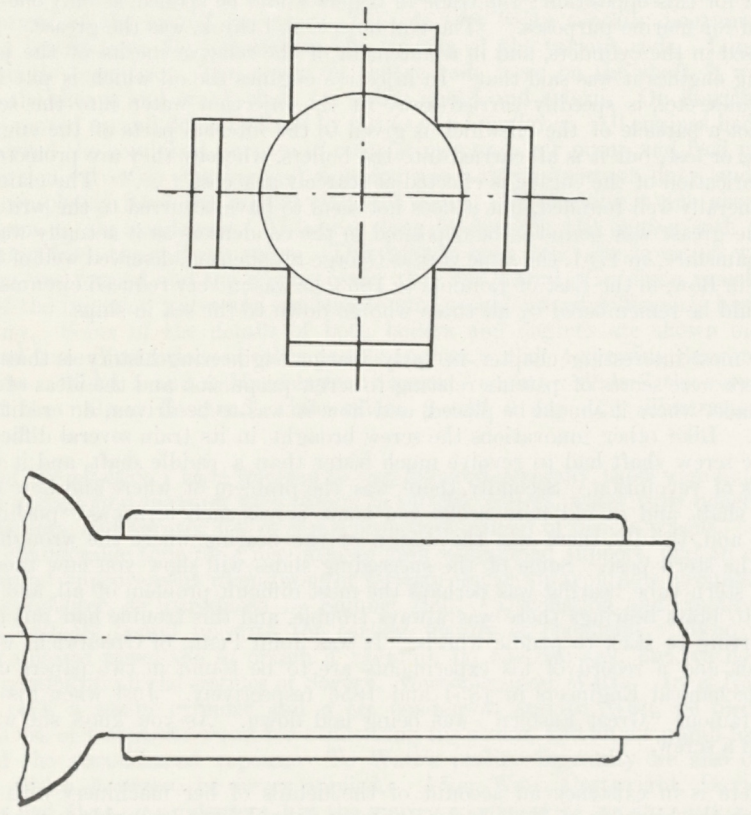
Field's notes and sketches are as follows :—

GREAT EASTERN, MARCH 15TH, 1860.

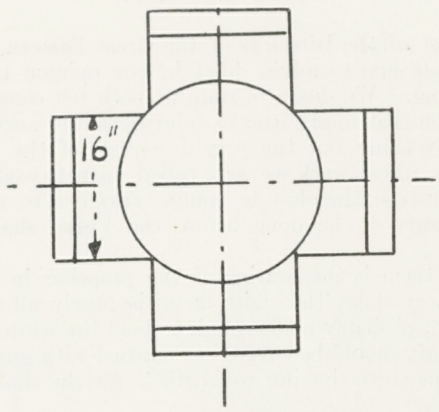
Went on board with Mr. Penn to examine the engine with a view to ascertain and recommend any improvements to render the engines more perfect.

The bearing of the screw propeller seemed to us to be the most important as well as the most difficult part to make any alteration or improve.

At present the shaft width is two feet diameter, is borne in stern, in a bearing eight feet long.



SKETCH I.



SKETCH II.

The four blocks are of wrought iron and are 8 feet by 16 wide. (Obviously 16 *inches* by 8 feet.)

$$\begin{array}{r} 96 \times 16 \\ 16 \\ \hline 576 \\ 96 \\ \hline 1536 \text{ sq. ins.} \end{array}$$

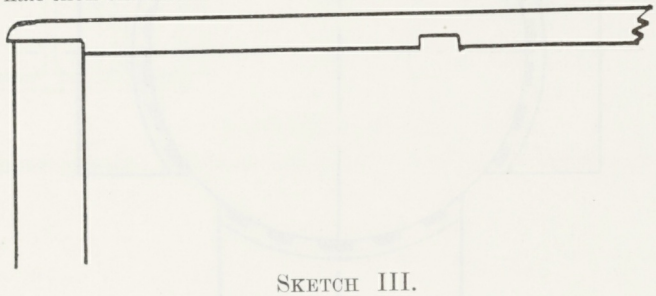
The shaft with propeller on and over hanging is supposed to weigh on the bearing about 54 tons.

$$\begin{array}{r} 54)1536(25 \text{ in.} \\ 108 \\ \hline 456 \end{array}$$

(Figures do not agree here, perhaps some mental reduction introduced.)

$$\begin{array}{rr} & 25 \\ \text{to a ton} & 20 \\ \hline & 500 \end{array}$$

This is under 1 cwt. to a sq. in., so that the weight is not out of the way. These blocks were faced with soft metal about half inch thickness.



SKETCH III.

The soft metal has been pressed out into thin lamina which had got to the top of the shaft which they say has gone down about half an inch. We were able to get down into the run of the Vessel and had one of the blocks, viz., the top one, taken out. The shaft did not seem to be cut at the outer end but at this end was rather scoured and red with rust. With reference to the propeller itself, we could not see it being under water.

We cannot say anything as to its strength. The four blades are fitted on a ball or boss with bolts and nuts of iron. The whole screw is of cast iron. Access to the end of the shaft should be by a large man-hole.

THE REPORT.

Gentlemen,

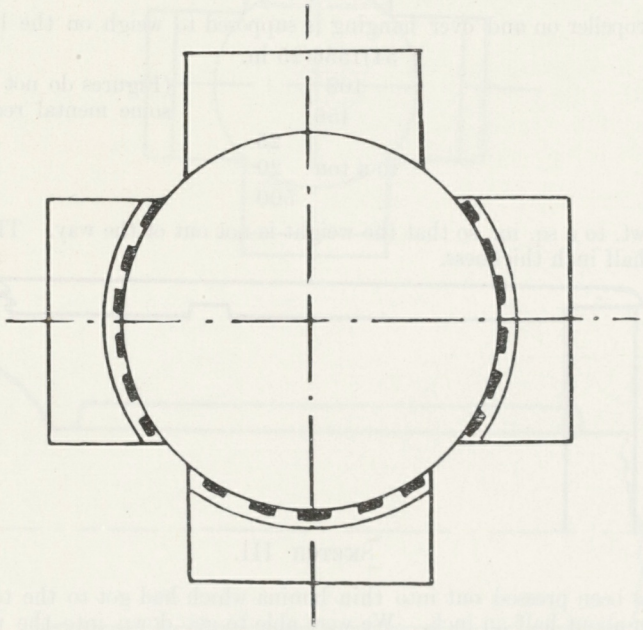
In accordance to the request of the Directors of the Great Eastern Steamship Company to examine the machinery in its present state and to advise what in our opinion the best course to pursue to send the Ship to sea early in the spring. We desire to state we both felt considerable reluctance as we always do to place ourselves in a position that might lead us to criticise the work of other Engineers engaged in the same path as ourselves. Nothing but the urgent request of the Directors and the strong desire expressed by both the Engineers, whose work we were called upon to examine, would have induced us to consent to the reference. We propose therefore to confine ourselves to recommendation of such work as in our judgment will be necessary to be done before the Vessel shall embark on a voyage of any considerable length.

The first in importance of them is the bearing of the propeller in the stern of the ship. This at present is in a very unsatisfactory state, the white metal is nearly all squeezed out and must soon be working on the wrought iron bed, probably made rough to hold the white metal in.

We could direct that the shaft should be covered or encased with gunmetal or brass, and that a gunmetal tube should be fixed in the stern, having wood fillets for the shaft to turn in. This is the only permanent for propeller shafts.

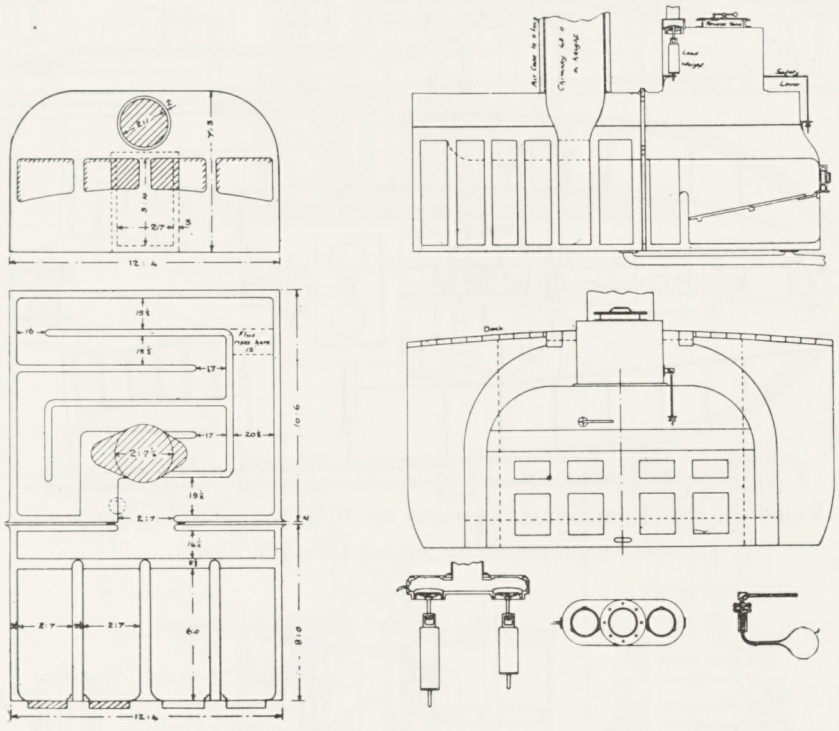
We could also direct that the propeller was so constructed that it might be taken up through a well hole from the deck, so that any time it might be repaired or replaced while afloat. Such an arrangement is most desirable for Vessels leaving home on distant voyages away from docks or any means of getting at the propeller.

However as neither of these alterations can be made without an entire reconstruction we have considered that the present wrought iron blocks which contain the white metal should be planed away to the extent of about two inches and a thick brass or gunmetal bearing fixed upon these slabs to have dovetail grooves cut in them, to receive slips of wood so that the bearing should be alternatively brass and wood.

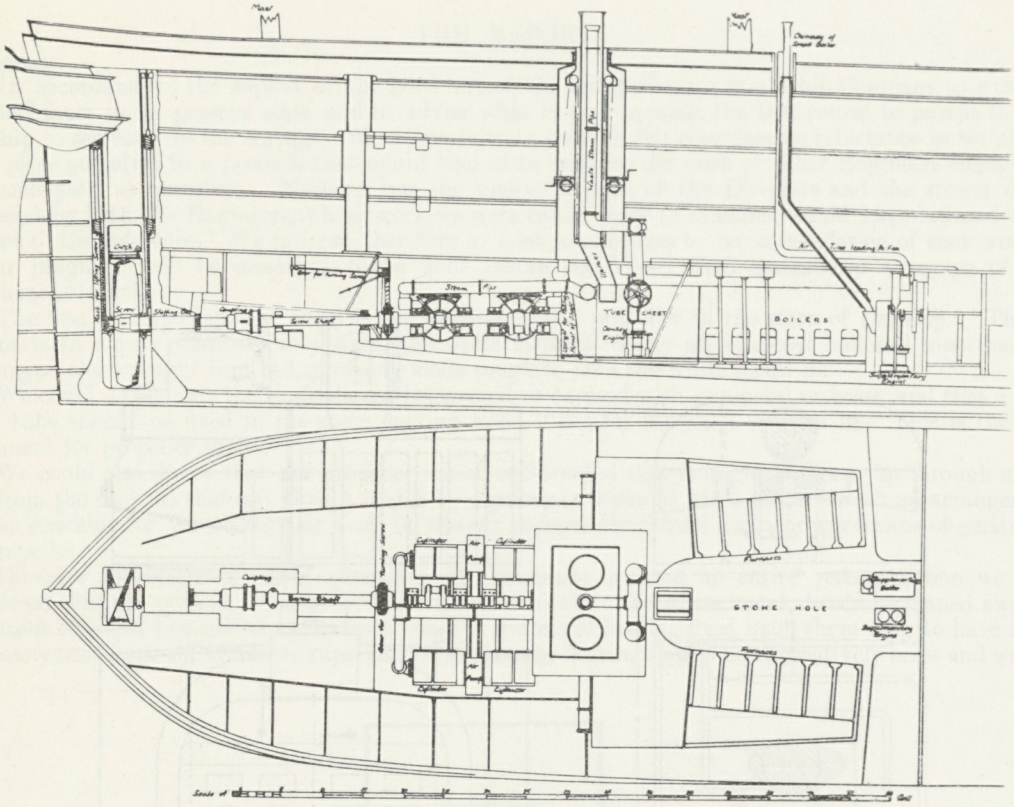


SKETCH IV.

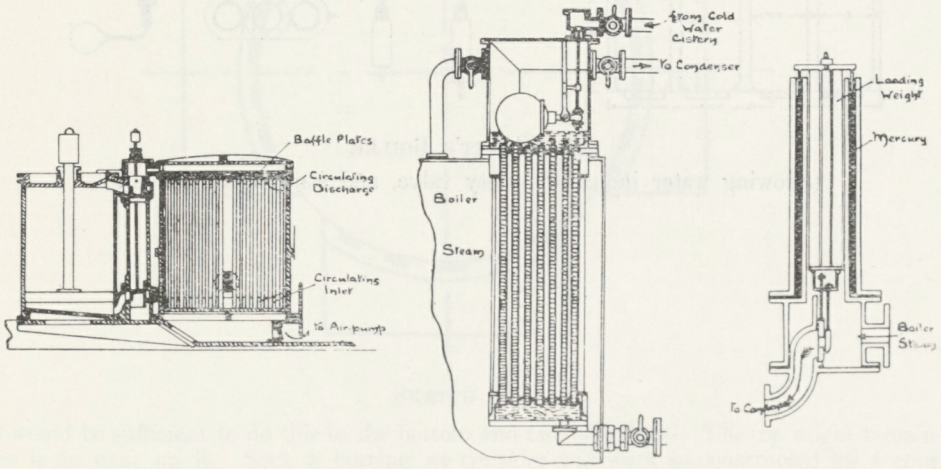
This would be sufficient to do this to the bottom and two side slabs. The top might remain as it is. There is no wear on it. Such a bearing we consider will work so constructed for a considerable time and quite sufficient for a voyage to New York and back. The operation can be effected while the Ship is afloat and in her present situation.



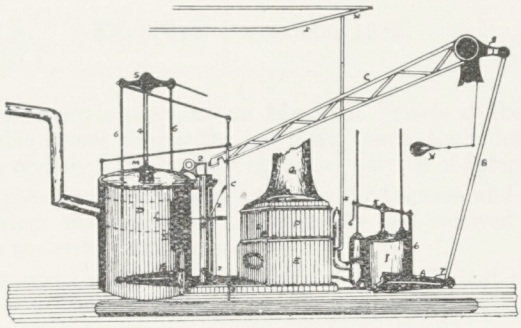
1.—Comet's Boiler
(Showing water indicator, safety valve, and atmospheric valve).



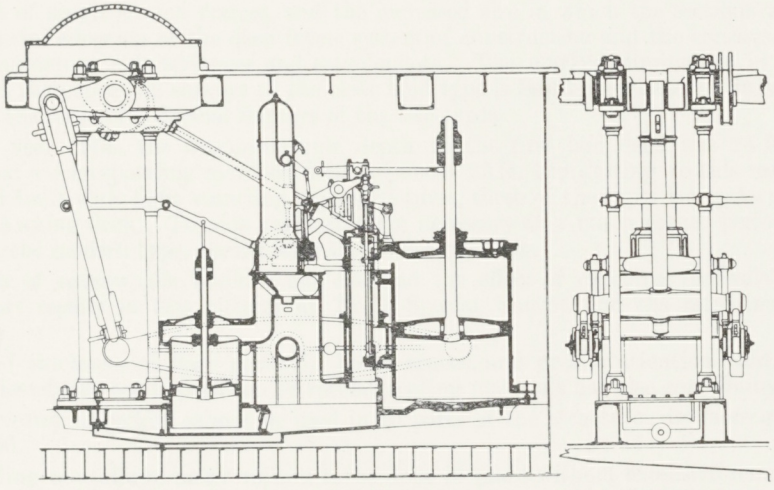
2.—Vertical and Horizontal Sections of H.M. Screw Steam Ship "Ajax" (Showing upright for taking thrust of shaft).



3.—Surface Condenser, Still, and Steam Saver, included in Samuel Hall's Patent of 1836.



4.—Comet's Engine without the Framing.



5.—Side Lever Engine Constructed by D. Napier, 1844.

NOTES ON SPECIAL SURVEYS OF MERCHANT VESSELS AND TANKERS.

By T. SHAW.

Read 5th December, 1935.

The extent of repairs and renewals necessary on Merchant Vessels at the respective Special Surveys has diminished to a considerable extent during the last thirty years, the reduction has not been gradual, but has occurred in periods, a review of the underlying causes may be of interest.

Credit for part of the improvement must be accorded to the Owners, and their Superintendents, with the exception of the war period, the upkeep of the structure has received increasing attention with accrued satisfactory results in the reduction of cost.

An aftermath of the war was the extensive renewals necessary in boiler room and deep tanks, this experience in certain cases was a blessing in disguise, inasmuch as it drew attention to the necessity for scaling and coating to be done every four years.

Evolution in the design and construction has, however, played the major part in the improvement. The most beneficial change, so far as upkeep is concerned, was the substitution of bulb angle or channel sections in place of built framing, consisting of frame and reverse frame. The introduction of the present standard profile of bulb angle sections has also prolonged the period before renewals are necessary; reference to this point is made later in the paper under remarks on repairs to framing.

The adoption of single section frames, and the increased size in which the sections were obtainable resulted in the general adoption of the deep frame system of construction and the consequent omission of web frames and numerous side stringers and attachments. The marked diminution in the volume of repairs, labour and time spent on surveys of the clear hold type is best appreciated by Surveyors who have had experience at the respective Special Surveys of the two types.

Prior to the year 1906, the maximum rule depth to the first laid deck was 24 ft. measured at the centre line, and a corresponding moulded depth of about 23 ft. 1 in.; owing to this restriction vessels were designed and built with light scantling superstructures, three of the types being Awning deck, Spar deck and partial Awning deck. Topside renewals were necessary at a much earlier period in the life of the vessel than in the modern type, particularly in the deck plating.

The omission of narrow side bunkers has also had the effect of reducing renewals, as it was not uncommon to start repairs in this vicinity at No. 1 Special Survey, and the ratio increased at each subsequent survey.

The increased thickness of floor plates in boiler spaces, and greater attention paid to scaling and coating has been beneficial, the application of special coating materials has also contributed to longer life.

Hydraulic riveting unluckily cannot be used in all parts of the structure; its more general adoption would be welcomed.

Electric welding now allows many repairs to be done in place without extensive removals; reference to jobs on which it may be used to advantage follows in various sections of the paper.

General.—The arrangements and procedure in carrying out Special Surveys devolves upon the Owner's Representative and the Repairers.

In establishments with a large volume of work it is customary to prepare a list each morning, before the arrival of the Surveyor, of the respective jobs ready, and the suggested sequence of examination. As the arrangements are made after careful consideration, not forgetting the time at which the respective Owner's Representatives can attend, the Surveyor should endeavour as far as ever possible to carry out the programme as arranged, and remember that the expedition he displays in carrying out his duties is a material factor in facilitating the progress of the work.

At each visit on the respective vessels, the Surveyor should be accompanied by an Owner's Representative and a responsible Official of the Repairer's Staff.

The sequence in which the work is done is dependent on many factors, but whenever possible the requirements relating to chipping and scaling should be notified, and the internal examination of boiler room, deep and peak tanks carried out at an early visit.

When deciding upon repairs and renewals, the most economical manner in which they can be done, consistent with efficiency, should be a primary consideration. In many cases the raising of a butt will obviate extensive removals. The use of a hand hammer on plates up to $\frac{7}{20}$ in. thick in conjunction with their condition should decide when test holes need be drilled; above that thickness, and on plates over beams two spaces apart, hammering is not to be relied upon, in case of doubt test holes should be drilled. The Surveyor should mark the position for drilling. In deck plating the thinnest part is usually in the vicinity of the overlap butt, or in way of steam pipes, and alongside the toes and heels of sectional material.

EXAMINATION IN DRY DOCK.

The rudder should be placed amidships at time of examination, twist can be most readily detected in this position and the alignment of the quadrant in relation to the rudder is more easily checked, the main post should be chipped in way of all the arms, grooving in this vicinity is not so common since the post has been increased in diameter in way of the arms, when slight defects are found it is advisable to "smooth up" by electrical deposition, in case of deep grooves the defect should be cut into with a narrow chisel and the Surveyor should satisfy himself of the absence of fracture before smoothing up. It is not a rule requirement for the rudder to be lifted at times of Special Surveys, although it is the general practice to do so. The condition of the stern frame gudgeons and of the pintles in them, also the clearance vertically between the arms and the gudgeons should determine the necessity or otherwise of lifting. At Special Survey No. 2 and all subsequent Special Surveys, the main post should be examined for wear in way of stuffing boxes, oxidation is often found at the fore side of the rudder coupling between the bolts, provided the flanges of the coupling are closed it need not be disturbed.

Stern frames, if of cast steel, should be carefully examined in the vicinity of all junctions of varying section, also both forgings and castings in way of the scarphs and gudgeons.

Shell Plating.—Indents and set up. It is difficult to describe specific cases where fairing should be insisted upon when the Owner's Representative is of the opinion that repairs are unnecessary, the following suggestions are an indication of customary practice.

When the indents are between frames it is unnecessary to fair the plating, riveting and caulking should, however, be examined. In cases of set in, where the sectional material in addition to the plating is deformed, fairing should be done. In cases of minor gradual set up of the bottom plating, and there is no buckling of the internal members of the structure, repairs are unnecessary. In small colliers and coasting vessels, usually with only one hold and no double bottom, gradual set up of the bottom is sometimes found extending over the length of the hold, and transversely on the flat of the bottom on several strakes, decreasing in width at the ends, in these instances consideration should be given to the question of introducing additional stiffening in the form of keelsons.

The position of all deformation should be noted for reference when carrying out the internal examination. In addition to general examination of all surfaces, particular attention should be given to the plating in way of the fore peak. Although panting fractures are not common, and ordinarily do not occur until the vessel is about eight years old, damage has occurred at an earlier date. In a paper read by Mr. A. Urwin before this Association (1929 session) a comprehensive description and the position in which they take place is given. The best method of effecting repairs can only be determined after careful examination of each case, the fitting of shell doubling plates in addition to welding in way of the fracture is the most general and effective remedy.

When the fracture occurs at the end of stringer lugs which have been fitted short of the frames, new lugs bearing on the frame on shell flange should be fitted, or where space permits a tee bar fitted. It is a preferable arrangement to fit double lugs in place of a single double riveted lug. When the fracture is situated at the end of a stringer plate, stopped one frame space short of the stem, a tee bar should be fitted in the forward space in addition to a shell doubling plate.

In a few vessels still in commission, side bracket plates attached to transverse bulkheads and shell are fitted, fractures in the shell plating frequently occur at the toe of the bracket. After the vessel is eight years old, the best method of repair is to fit a shell doubling plate, remove and not refit the bracket. In vessels say about twelve years old and upwards, the after keel plate overlaps and the seams of the keel and garboard plates in way of the forefoot are liable to corrosion and the caulking edge is destroyed, this defect can readily be made good by chipping and electric welding. Plating in way of all outside mouldings and side fenders should be chipped and carefully examined.

Cable chafe does not take place to any appreciable extent until the vessel is about twelve years old, and is most marked on the outer edge of the stem plating, occasionally on vessels of full form and with straight stem it may be observed several feet aft of the stem at the upper edge of the forefoot. In way of the plating faying on the stem bar, repairs are unnecessary until the caulking edge is badly worn. Where it is possible to cut back and obtain a new caulking edge, this arrangement is satisfactory, in extreme cases the plates should be removed (there is no objection to raising butts on long plates) a less preferable arrangement is the fitting of a "bible" plate. Worn plates, clear of the stem, when deteriorated below permissible thickness should be renewed.

Drilling of Shell.—Except in small vessels and others engaged in special trades, drilling other than in locally deteriorated areas is rarely necessary before the maximum rule limit, 24 years, is reached. The usual position fixed upon for rule requirement drilling is the second frame space abaft collision bulkhead, two spaces forward of after peak bulkhead, amidships in way of side bunkers, if fitted, and if no bunkers are fitted, position determined after inspection of internal surfaces and position of auxiliary machinery. In colliers with large hatchways the position aft is sometimes altered to the first frame space forward of the after hatch end.

Renewal of plates in isolated areas which are below minimum rule thickness requirements presents no difficulty. In cases where it is found necessary to double a strake, the operation is simple when the original plates are butted and inside straps fitted. The presence of overlap butts complicates the job.

Alternative methods are (*a*) cutting the inner of the two shell plates at the end of the overlap and fitting an inside strap; (*b*) butting the new plate against the end of the existing overlap butt and extending the doubling plate beyond the original lap, thus raising a new butt immediately aft of the original one; the latter method is an ugly job and is not recommended. In all cases, apart from cost, renewals are preferable to fitting doubling plates in way of existing overlap butts.

Rivets.—Odd slack rivets are more prevalent in way of the after peak than in any other part of the shell. Worn specimens occur first in the after keel plate and in subsequent periods at the fore end of the vessel in way of the keel and adjoining shell plating, this defect is most pronounced in colliers running with excessive trim by the stern in ballast condition. Pitted rivets, until a few years ago, were a rarity and confined to the flat of the side between "wind and water," at the present time defects are more common and occur in various positions, coating the points with gold size or other special composition has been found effective in arresting the trouble. In a few instances electric welding has been tried. Badly pitted specimens should be renewed.

Testing of Tanks.—Double bottom:—It is not customary to examine the ends and divisions under pressure, they should be hammer tested at time of internal examination; the thinnest part of the plates is usually at the toes of the boundary angles.

Peaks and deep tanks. No. 1 Special Survey:—When the crown is sheathed, the height of the water when it has come to rest in the air and sounding pipes should be noted at commencement of the examination of bulkhead and shell, and checked on completion. Provided there is no change it is unnecessary to remove sheathing.

Nos. 2 and 3 Special Surveys:—The same procedure may be followed as in No. 1 with the addition that part of the sheathing should be lifted, preferably at the lowest point, and the surface of the plating examined. In the event of the presence of scale, lifting should be extended until found satisfactory.

It is not a rule requirement for any ballast tank to be tested in dry dock, and unless there is evidence of considerable leakage in the shell, it is not customary to do so.

CHIPPING, SCALING AND COATING.

The rule requirements are :—Special Survey No. 1, and Special Survey No. 2, "The framing and both surfaces of shell plating are to be exposed, and cleaned and coated where necessary"; discretion may therefore be exercised.

The trade in which a vessel is employed and the extent of the scaling and coating done between surveys should receive consideration when deciding upon the work necessary to be done at the time of survey. In the case of colliers employed continuously on short voyages, it is not possible to do any chipping or painting between surveys and the general practice is to scale and coat throughout at times of survey. On vessels engaged on long voyages and running in ballast trim in one direction, and there is evidence that work is being done systematically, provided there is no existent heavy scale, part of the cleaning and coating might reasonably be left to be done as the opportunity occurs.

Special Survey No. 3 :—"All rust is to be removed from the iron and steel throughout the vessel and the surfaces are to be recoated"; the presence of rust between the paint and the steel or iron, can be readily detected by the use of a hand hammer.

There are still a few vessels in commission with built frames, i.e., frame and reverse frame throughout, and in some cases locally at the fore end of the fore hold instead of increasing the depth of the single section. In all these cases rust in varying thickness will be found between the faying surfaces, unless it is thick or the riveting started it is better left undisturbed.

In double bottoms all scale and blobs should be removed, if the cement wash is in good condition no objection need be taken to a thin superimposed coating of mud.

To ensure that scaling is properly done, it is advisable to institute a system that coating is not to be started until the respective areas have been scaled and passed; special attention should be directed to the surfaces in way of heel and toe of all sectional material and the underside of all horizontal surfaces.

Internal Examination.—Special attention should be given to the following parts of the structure: After peak tank; all rivets through shell lugs and stringer plates, beam knee brackets, shelf plates to bulkheads, in top and bottom connections to wash plates, and where floors are fitted above the stern tube, to the end rivets through the frames.

Special Survey No. 2 and subsequent surveys to deck plating covered by sheathing or deck compositions. Fore peak tank, in addition to the items mentioned for after peak, examination of shell plating and stringer plates at ends of lugs. Deep tanks, similar to after peak tanks, plus ventilators.

Double bottom in way of holds, riveting through floor ends, radius of margin plates, wide spaced hold pillar feet, fixed bends of suction pipes and plates under sounding pipes.

Engine and Boiler Room Tanks and under Donkey Boiler if placed in Hold. Special Survey No. 1 :—Wastage of material at this survey is usually slight. The removal of all scale, debris from tank top, thorough cleaning of bilges and recoating should, however, receive careful attention.

Special Survey No. 2 :—While it is not customary to find serious wastage at this time, a thorough examination is necessary, ordinarily where deterioration occurs it is most pronounced on floors and intercostal plates immediately under the boilers, on the tank top at the fore and after ends of boilers (particularly fore end in way of stoking platform), at fore end of engine seating, in way of condenser and under cocks and drainpipes and in way of the donkey boiler from centre line to first intercostal.

Special Survey No. 3 :—All parts should be suspect. Decks covered with compositions :—The presence of white blobs on the under side of the plating is an indication of wastage. If the surfaces are free from discoloration, a satisfactory examination can be made by the use of a hand hammer.

Galley floors, coal shoots and plating in way thereof, plating in way of steam pipes, decks in way of permanent bunkers, air and sounding pipes, ventilators, ash shoots, donkey boiler floor if in 'tween decks, and the structure in way of all openings in decks.

Part renewals, reinforcement and repairs. Framing :—There is no objection to cropping and part renewal provided a satisfactory butt bar be fitted, say, bulb angles, back bar of the same section as the original material, length in proportion to size, say, from 2 ft. 6 ins. to 3 ft. 6 ins.

Channel Sections :—Similar arrangement to bulb angle, with additional face plate covering the inner flanges. Angles :—Back bar.

REINFORCEMENT.

Bulb angles:—In smaller vessels, particularly colliers, in sections rolled before the introduction of the British Standard profile, the web is often badly wasted at the root of the bulb; in these instances renewal is necessary. Where the wastage is general on the web, reinforcement may be introduced in three forms, viz., flat plate, bulb plate and reverse frame. Ordinarily they need not be extended beyond the brackets at top and bottom.

Channels:—The usual method is to fit a reverse frame, the depth of the faying flange varying according to the extent of the deterioration.

Angle frame:—Fit reverse frame. In colliers, when discharging is done by grabs, it is often placed bosomwise.

Local deterioration in erections:—Fit brackets spaced as considered necessary, or alternatively, back bar to shell.

BOILER ROOM TANKS.

Floors:—Deterioration is usually most pronounced at the edge of themanholes and at the toe of the boundary bars. Alternative methods of repair are fitting doubling plates or vertical stiffening angles. When the plates are locally wasted it may be necessary to fit narrow doubling plates in combination with vertical stiffening angles. Provided the deterioration is general and not excessive, fitting vertical angles is the most effective method of reinforcement. They should be placed at the edge of the manholes with the heel towards the opening, and take jointer rivets through the frame and floor top bar, size say, $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{8\text{-}10''}{20}$

Fitting doubling plates, except in way of local wastage, is rarely a satisfactory job. They can only be fitted in short lengths and narrow widths (even if a slot is cut in the tank top plating). To be effective they should be joggled over all boundary bars, and it is difficult to reclose the work and make a sound job of the riveting through three and/or four-ply work.

When renewals are necessary to the tank top plating, it is customary to renew the floors and other wasted material. In cases of general wastage of tank top plating, renewals are usually effected by cropping transversely from the edge of the rider plate to the margin plate in a straight line at forward and after ends of the area to be renewed, and the new plates are fitted transversely with double riveted seams. Provided there is a minimum height of 18 ins. between the tank top and the lowest part of the radius of the boilers, the work can be done without lifting the boilers, viz., additional cropping is done at the inner fore and after side of the stools, the plating between the stools is then removed, new floors fitted in way of this space and covered by new transverse top plates. The weight of the boilers is then transferred from the stools to wood chocks on the new plates, the stools and plating in way thereof can then be removed and renewals completed.

Wastage of tank top plating in way of engines is usually local. Ordinarily, a satisfactory job can be made by fitting doubling plates. In extreme cases it may be necessary to lift and remove the engines.

TANK FLANGE PLATES AND CONNECTIONS.

In vessels with web frame construction, defects are usually confined to the vicinity of the web frame feet. Occasionally fractures develop in way of the adjoining floors, odd slack rivets are found in various positions, but principally the top rivets in the connection angle. The latter trouble rarely exists when the riveting at time of build was done by hydraulic power. The usual method of repair is to fit local doubling plates, reamer all holes when renewing rivets, and fit the new rivets a size larger.

In recent years, in deep single deck type vessels, and more particularly where increased size of outer connection angles and additional riveting have been fitted in lieu of gusset connections, damage is more frequent in the form of fractures in the radius of the margin plate, and started or sheared rivets in the floor and connection angle. In a few cases the flanges of the angle have been fractured.

The damage rarely extends beyond the half length. The disposition in this area varies, in some cases the fractures are massed and in others intermittent. Loose rivets in the floor end connection angle

occur in the vicinity of the fractures and generally a few spaces beyond. It is not uncommon to find fractures on the inner surface of the margin plate which have not extended through the full thickness. This feature directs attention to the necessity of making a thorough internal examination before deciding the extent of the repairs.

Alternative methods of repair are illustrated in Fig. 1 "A" and Fig. 2 "B." "A" has been fitted in many instances and proved effective. "B" is only adopted where the angle and radius of the margin plate is easy. When design "A" is fitted, it is important that the inner rivet in the vertical flange of the gusset angle and the bracket plate, and the horizontal flange on the tank top, should be arranged as close as ever possible.

Variation in design of original construction should be considered when deciding method of repair. The following suggestions are submitted for general application.

If doubling plates are fitted they should extend at least one frame space beyond existing fractures and of a width about half the depth of the margin plate, the lower edge being placed nearer the upper of a pair of rivets to ensure the joggle of the new connection angles being clear of holes. When the space from the inner edge of the radius of the flange plate and the outer edge of the tank top plating is sufficient to take a longitudinal row of rivet holes, it is a satisfactory job to butt the doubling plate against the tank top plate and butt caulk. When the width of the tank top portion of the margin plate is considerable (as in the case of vessel "A") it is advisable to fit the doubling plate of sufficient width to take the end rivet in the floor top bar. When doubling extending over a considerable length is necessary, the plates are usually butted against the overlap of the existing margin plates and stopped at the near side of the next overlap.

On vessels where gussets have not been fitted at the time of build, in addition to the doubling plates, either plate or angle gusset connections should be introduced, preferably the latter, say 6 ins. by $3\frac{1}{2}$ ins., with the larger flange horizontal, spaced two to three frame spaces apart, dependent on the depth of the vessel. Where the space is restricted it may be necessary to fit 6 in. by 6 in. angles. Where started and/or sheared rivets are found in the flange of the angle connection to the floor plate, the minimum repair should be to reamer the holes and fit a larger diameter rivet. If the defects are extensive and massed the introduction of a larger angle and additional row of rivets is desirable; in both instances the rivets should have countersink points, not knobbled. In all cases it is advisable to weld fractures.

ENGINE SEATINGS.

Damage is more often found on the semi-box type, very occasionally in box type and on raised tank tops, and is usually confined to the riveting through the flanges of the angle connections to the seating top plate. The holding down bolts should be examined, and if any are found not tightly screwed up attention should be drawn to the slackness. Where defects are observed in the riveting, the seating should be properly cleaned and small hammer tested throughout. Slack and started rivets respectively should be indicated by paint of different colours.

In extreme cases it may be necessary to remove the engines. Before making this decision careful consideration should be given to the following factors:—(*a*) the extent of the damage; (*b*) the location of the rivets in relation to the accessibility for renewal; (*c*) application of electric welding; (*d*) the introduction of efficient reinforcement with engines in place.

In view of the dissimilarity in design and variation in scantlings, each case must necessarily receive individual consideration. The following suggestions for general application are submitted:—

With Engines Removed (all types of seating).—If there is evidence of "breathing" in the top plate, the plate should be removed and renewed of increased thickness. Semi-box types: Cover open outer side with continuous plate lapped to the top plate and scalloped out where necessary for accessibility, fit double connection angles on bracket plates in one length to top and side plates. If the shape of engine bed plate permits, where bracket plates have not been originally fitted on the inner side of the vertical longitudinal plate they should be added.

Engines not Removed.—As far as possible the foregoing suggestions should be carried out; where bracket connection angles cannot be fitted continuously the new portion should fit against the old and be welded at the butt.

It is advisable in all cases to electric weld the horizontal flanges of angle connections to the top plate. Unfairness in holes, however slight, should be rectified by reamering and fitting larger diameter rivets, and odd additional rivets can often be introduced to advantage. Hydraulic machine riveting should be adopted wherever possible.

The points of the rivets through the top plates should be finished high topped, and never extend beyond the circumference of the hole, where it is necessary for them to be flush with the top plates in way of engine bed plate or metal chocks the points should be removed by a rotary buffer.

A diagrammatic sketch of the seating, showing position of started rivets will be found useful when discussing the work considered necessary to be done.

HATCH COVERS (WOOD).

Should be examined in position, there are occasions when it is not practicable to comply with this requirement in its entirety, in such instances the length of the covers should be checked from measurements taken in the respective bays (this can be most readily done with a light batten), and the examination then carried out in a similar manner as when in position by examining all surfaces.

Permissible tolerance in length is dependent on the width of the bearing surface, in modern hatchways with supporting beams athwartships, one inch is a reasonable limit, in the case of centre wood fore and afters and minimum rule width of rest bar on the hatch coaming plate, the tolerance should be decreased proportionately and the wear which is common on the corners of the fore and afters (if not condemned for this reason) taken into consideration in fixing the permissible allowance.

The common defects on which condemnation follows comprise wear, abnormal warping, bad splints or rents (not sun cracks), numerous and large loose knots, breakage in way of handholds and through bolts. Wear should be distinguished from shrinkage, inasmuch as a cover reduced in thickness by atmospheric conditions is still as strong as when originally fitted, the maximum shrinkage due to temperature is about one quarter of an inch in a two and a half inch cover.

The quality of the replacement timber should be similar to that fitted in new ships, viz., U.S., Swedish or Petrograd or equal clean, long grained, good quality, well seasoned and reasonably free of sap, knots and shakes; ordinarily timber branded U.S. I, II and III is suitable for hatch covers, IV, V and VI are not.

STEERING GEAR, CHAINS AND LEADS.

Demarcation of the parts examined by the Ship and Engineer Surveyor respectively should be arranged; it is customary practice for the Engineer Surveyor to examine the steam or electric gear and the Ship Surveyor the remainder of the fittings. It is essential that all grease should be removed from the various fittings before the examination is made, the common practice of putting the chain through an open fire, except when the heat is only sufficient to remove the grease, should not be allowed. In cases where annealing is specified the Author desires to associate himself with the views expressed by Mr. C. S. Porter in his paper read last Session. In all cases of part renewals of chain where new links are fitted, the length should be tested on completion, and the rule requirements complied with for entire new lengths. Hand gears, in addition to being examined, should be worked.

When relieving tackle is adopted as the second means of steering, the whole of the gear should be examined in position, and on completion of examination stowed in a position readily accessible at all times. All other fittings not specifically mentioned in the foregoing remarks should be carefully examined.

PRELIMINARY SURVEY.

Requests to make a preliminary survey prior to putting a vessel through the Rule requirements of Special Survey when twelve years old or older, are becoming more frequent; in some instances the request is made with a view to the preparation of a specification sufficiently detailed to obtain the estimated cost of re-classing the vessel, in other cases to arrive at a decision whether to scrap the vessel or proceed with the survey. The requests are more frequently made for tankers than merchant vessels.

When the request is acceded to, it should be distinctly understood that the recommendations made are a general indication of repairs required, and that modifications may be necessary.

In the case of tankers it is usual to confine the internal survey to two half tanks on opposite sides of the vessel, one of which has been regularly used for ballast purposes, and both clear of the pump room and cofferdam bulkheads. Steelwork in the two selected compartments to be scaled and cleaned, and drilled where considered necessary, and a general survey made of the structure clear of the oil compartments.

The survey of merchant vessels should include internal examination of peak and deep tanks and boiler room tank, drilling to be done where considered necessary.

TANKERS.

Thirty years ago renewals necessary in consequence of corrosion were only slightly in excess of the repairs to merchant vessels at the respective special surveys. At that time all vessels were constructed with transverse framing. Apart from deterioration common to both merchant ships and tankers, there were frequent cases of fractured bulkhead plates in way of the side stringers and bottom keelsons. The usual method of repair in these instances was to fit local doubling peaks and in all cases to extend the angle connections beyond the location of fracture. Occasionally fractures occurred on the bottom shell in the larger size vessels (more particularly on the garboard strake), repairs were effected by fitting doubling plates or renewals, in the latter case the thickness of the new plating was increased at least $\frac{1}{20}$th of an inch.

In recent years the ratio of deterioration due to corrosion has gradually increased in vessels carrying white oils; in many instances the practice of limiting the carriage of white oil cargoes to a period of eight years is being adopted and, subsequently to carrying black oil cargoes, this arrangement has resulted in extending the life of vessels and reducing the cost of upkeep.

In vessels where the cargoes have been restricted to black oils there has been no marked change and when trouble is experienced it is local rather than general.

In most instances owners prefer to carry out all the testing of oil compartments in dry dock; provision, however, is made in the Rules for cases where it is decided to do only part of the work in dry dock, in these instances the vessel when afloat should be placed in a position to allow of the examination of the upper external surfaces of the shell plating when under pressure.

Cleaning of Tanks.—Oxidization occurs in two forms, flake scale and encrustations. The former is easily removed ; if in the latter form, i.e., adhering closely to the surfaces, the appearance may be very misleading. Small areas should be cleaned and the thickness and condition of the structure under it ascertained before deciding the extent of the scaling required, ordinarily thin coating need not be disturbed, special attention should be directed to the thorough cleaning of the bottom and shell plating. In one case at Special Survey No. 3 the weight of scale removed was over 160 tons, 60 to 80 tons are not uncommon.

A basis for the permissible reduction in thickness before renewals are required is necessary. The respective positions and condition of the plating should be considered and may warrant modifications. Particulars of the thicknesses and renewals effected on the transverse bulkheads of a vessel, designated Tanker "A," are given in Fig. 3. The basic standard worked to for renewals was a diminution of 25 per cent. on the upper strake of plating, increased in gradations to 30 per cent. at the base. The total renewals in the structure in this case was over 450 tons. Where wastage is general over large panels, the introduction of intermediate stiffeners may be a satisfactory and preferable method of re-inforcement.

For sectional material, a similar basis as for plating. 25-30 per cent., might be adopted, provided the location of wastage in relation to strength $\left(\frac{I}{Y}\right)$ is borne in mind.

To indicate all the positions where deterioration may be expected in vessels carrying white oils, from Special Survey No. 2 (inclusive) and onwards, can be best summarised by stating that all surfaces should be examined.

Speaking generally, the deterioration on bulkheads, both transverse and longitudinal, including plating and sectional material, will be found most pronounced at the top, and gradually diminishing in intensity in the downward direction. Sectional material is usually found most reduced in summer tanks in

(both on the shell and decks) in the expansion trunk, and the shell longitudinals immediately below the second deck. Local wastage, often in the form of grooving, occurs at heels and toes of stiffeners. On the bottom shell large areas of wasted plating may be found interspersed with localised patches. In other cases there is localised deep pitting. Grooving alongside shell seams and at the ends of overlap butts is not uncommon, and usually worst in way of the garboard strake; wastage is common in the vicinity of the foundation angles of the bulkheads, both transverse and longitudinal, and to a lesser extent in way of the longitudinals.

The following particulars obtained from a vessel, eight years old, carrying white oils, illustrates the variation of wastage in the topside wing structure :—

	Reduction per cent.	
	Mean.	Variation.
Trunk side, top plate	22	20–25
„ bottom plate	15	15
Longitudinal stiffeners on trunk side	15	Nil–25
Summer tanks, side longitudinals	30	20–43
„ deck „	31	20–33
Main deck stringer plate	19	9–32
„ middle strake	21	
„ inner „	20	

The reduction in thickness on bulkheads in single and double oil contact respectively varies considerably. The following particulars were obtained from a vessel seventeen years old, and covers the area from main deck to base :—

	Per cent.
No. 1 tank, after bulkhead, single contact, mean reduction ...	12
No. 1 „ forward „ double „ „ „ ...	40
No. 3 „ after „ „ „ „ „ ...	43
No. 3 „ forward „ „ „ „ „ ...	42
No. 5 „ after „ „ „ „ „ ...	43
No. 5 „ forward „ single „ „ „ ...	14
No. 6 „ after „ „ „ „ „ ...	20
No. 6 „ forward „ double „ „ „ ...	37
No. 8 „ after „ „ „ „ „ ...	41
No. 8 „ forward „ „ „ „ „ ...	46
No. 9 „ „ „ single „ „ „ ...	12

All plates in way of the expansion trunk were renewed and are not included in the foregoing.

The mean reduction in thickness of the respective strakes of transverse plating was :—

	Per cent.
No. 1 top plate immediately below main deck	47
No. 2 strake	40
No. 3 „	36
No. 4 „	37
No. 5 „	32
No. 6 base plate	25

The actual reduction in thickness of the respective strakes varied, top to bottom, from ·159 ins. to ·124 ins.

Corrosion of rivets is freakish. Reference is more particularly directed to those in bottom shell plating, in some cases the heads are practically non-existent in small areas, in others the defects are interspersed, generally the worst examples are found in the centre line foundation angles and keel seams. At all surveys from No. 2 inclusive the strums on the pipe line should be removed, the shell examined in way thereof, and the pipe line examined in its entirety. Giving the pipe line one quarter turn periodically is now common practice. In vessels carrying black oils local pitting occasionally occurs in the bottom shell plating.

Shell plating is sometimes covered with Portland cement of sufficient thickness to cover the rivet heads. In the event of cracks developing in the cement and/or parts of it missing, a careful examination should be made. The following "Journal" extract refers to a typical instance :—

> "'B' strake plates found thin in way of Nos. 2 and 3 tanks, the diminution in thickness "extends for a considerable length between the edge of the seam of plating and the adjoining "longitudinal and is practically free from local pitting; wasted plates to be renewed, cement "clear of the wasted area was removed and the shell plating found in good condition."

The vessel in which the foregoing occurred is a tanker 440 ft. long and was eight years old at the time of survey, and had carried crude oil only, except on the last voyage, when the cargo was fuel oil. In tankers of considerable size, say 440 feet long and above, fractures have been found in way of the deep tank in the vicinity of the transverses.

Failures of material in longitudinally framed vessels, apart from fractures in way of local structure weakened by corrosion, are of latter years infrequent. The most common trouble was fracture in way of the corners of slots punched in transverses, etc., the present practice of doing this job in one operation by a special punch with tapered sides and radius end has reduced the susceptibility to fracture; occasionally slight deformation occurs at the ends of sectional material (also started rivets) on which brackets are not fitted.

In vessels transversely framed with strong longitudinal members, fractures sometimes occur on the bulkheads in the vicinity of the inner and/or top edge of the brackets connecting the deep longitudinals and/or side stringers to the bulkheads.

Repairs to Tankers in way of Oil Compartments.—In the case of the removal of shell plates, it will be found, even when the greatest care is taken in the operation of centreing, that some of the holes in the seams and overlaps of the plating not removed will be malformed to a more or less extent. Where the defect is slight the hole should be reamered and a larger size rivet fitted, in odd holes where the enlargement is pronounced a satisfactory job may be effected by electric welding and re-drilling, where this method is adopted the Surveyor's approval should be obtained before starting the job.

To obtain workmanship of the highest character, it is essential when plates are removed and refitted that the whole of the burr raised by original caulking should be removed; this operation is more satisfactorily done by planing; chipping when resorted to is often done in a perfunctory manner, the whole of the burr is not excised and entails re-caulking at subsequent docking. The presence of exceptionally heavy caulking indicates that the work had not been properly screwed up and closed.

The extensive use of injections (otherwise shots) should not be necessary, and should not be allowed in an attempt to remedy inferior workmanship. Punching holes a size small, and reamering, with good screwing up will tend to reduce the use of the putty pump, permissible exceptions may be made on collar and corner work.

When doubling plates are introduced on the caulking side of the structure, the original holes should be reamered and a larger size rivet fitted.

Shell Plating.—In cases of local pitting and grooving, a satisfactory job can often be effected by smoothing up with electrical deposition; the area to be dealt with and the corresponding respective cost of renewals is usually the deciding factor. Large areas call for renewals both in cases of pitting and wasting. Slight buckling of the plating and/or deterioration at the end of stiffeners on bulkheads can be most effectively dealt with by cutting off one of the existing boundary angles and fitting an angle with a deep flange in the vertical direction on the opposite side to the stiffener, 8–10 ins. × 3½ ins., taking the bottom rivet in the stiffener. Started rivets in the ends of shell longitudinals should be renewed a size larger, and anchor angles introduced, if not fitted originally.

In cases of fracture in plating at the end of connection angles, in addition to renewing or doubling the plate, where single, the new angle should be increased in length, and when double, one should be extended at least one rivet space beyond the other, there is no objection to cropping and renewing the upper portion only.

Rivets.—Badly corroded rivets should be renewed; in most cases the corrosion extends beyond the circumference of the rivet, but not to the extent to warrant the condemnation of the plates. In these instances, smoothing up by electrical deposition should be considered. Where similar conditions prevail in other parts of the structure, say, transverse seams of plating, an efficient job may be made by countersinking the hole and fitting rivets with countersunk heads in place of pan heads.

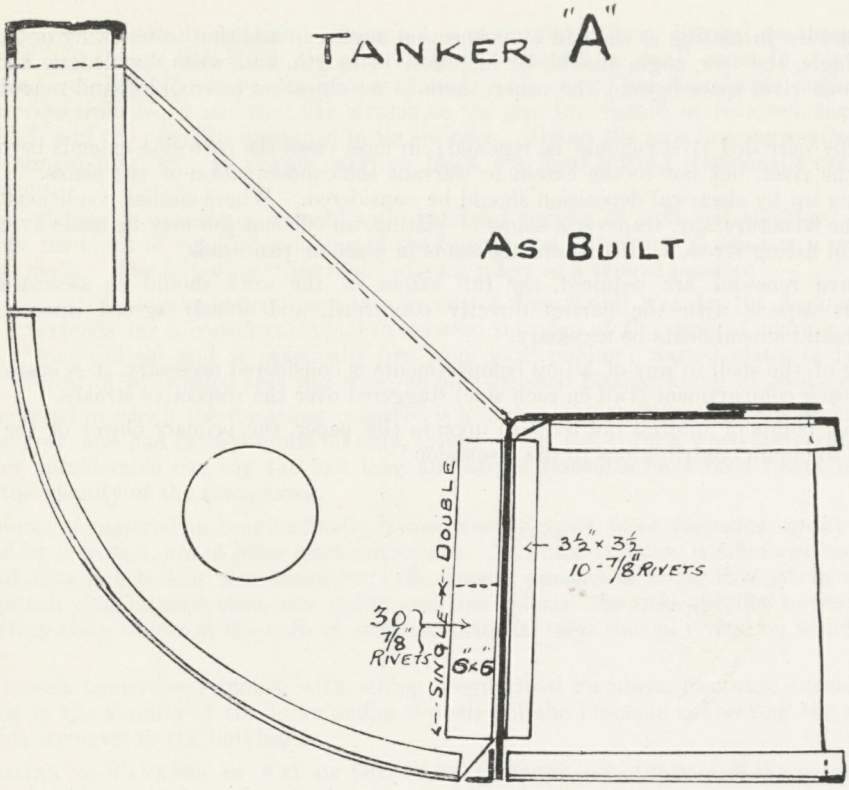
When extensive renewals are required, the full extent of the work should be ascertained and discussed in all its aspects with the parties directly concerned, and jointly agreed upon, only in exceptional cases should amendments be necessary.

When drilling of the shell in way of all oil compartments is considered necessary, it is customary to drill four holes in each compartment (two on each side) staggered over the respective strakes.

There are many points of interest not touched upon in this paper, the primary object of the author in submitting it is to obtain contributions to the discussion.

TANKER "A"

AS BUILT



AS ALTERED

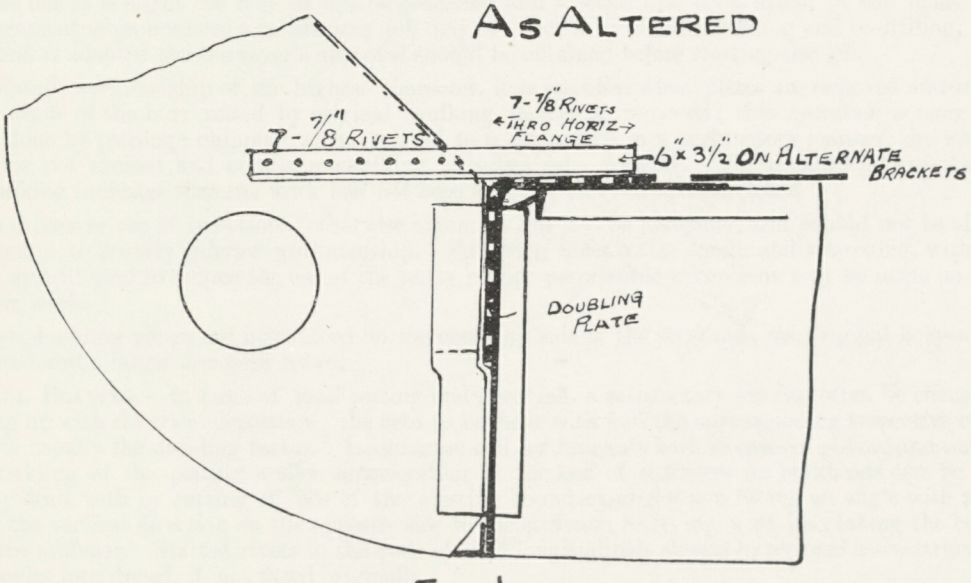


FIG. 1.

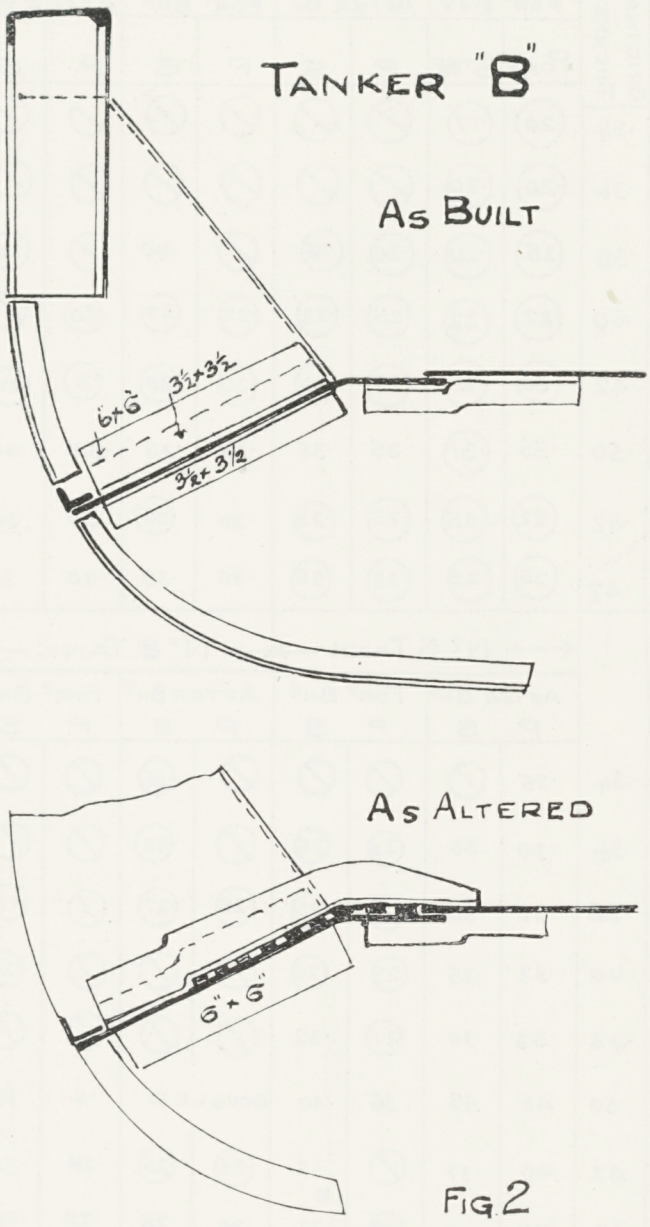


FIG. 2

TANKER "A"

TRANSVERSE BULKHEAD THICKNESSES

	Original Thickness	No 1 Tank For. Bhd.		No 3 Tank After Bhd.		No 3 Tank For. Bhd.		No 5 Tank After Bhd.		No 5 Tank For. Bhd.	
		Port	Stbd	P	S	P	S	P	S	P	S
Top Horiz.l Strake	·34	·20	·17	⌀	⌀	⌀	⌀	⌀	⌀	·28	·28
2nd "	·36	·20	·20	⌀	⌀	⌀	⌀	⌀	⌀	·30	·35
3rd "	·38	·25	·20	·20	·18	⌀	·40	⌀	·25	·30	·35
4th "	·40	·22	·22	·25	·23	·22	·27	·20	⌀	·38	·28
5th "	·42	·30	·25	·27	·30	·30	·30	·3	·22	·38	·33
6th " (Base)	·50	·35	·31	·35	·35	·35	·35	·38	·40	·45	·47
Vert.l Wing Plate	42	·22	·25	·25	·23	·30	·25	·30	·30	·40	·40
" Centre "	·42	·25	·25	·25	·25	·30	·30	·28	·30	35	·37

	Original Thickness	No 6 Tank After Bhd.		No 6 Tank For. Bhd.		No 8 Tank After Bhd.		No 8 Tank For. Bhd.		Top Plates in Expansion Trunk Renewed Throughout
		P	S	P	S	P	S	P	S	
Top Horiz.l Strake	·34	·25	⌀	⌀	⌀	⌀	·15	⌀	⌀	
2nd " "	·36	·30	30	·25	·25	⌀	·22	⌀	⌀	
3rd " "	·38	·30	·30	⌀	·25	·25	·27	⌀	·17	
4th " "	·40	·32	·35	·22	·20	⌀	⌀	⌀	·20	
5th " "	·42	·32	·30	·27	·32	⌀	⌀	⌀	⌀	
6th " "	·50	·45	·45	35	·40	DOUBLED		·4	·35	
Vert.l Wing Plate	·42	·40	·37	⌀	·35	·25	·25	·28	·30	
" Centre "	42	·35	·35	·18	·27	·30	·28	·28	·28	

⌀ Condemned. Not Drilled

○ Drilled & Condemned

FIG·3

DISCUSSION ON Mr. T. SHAW'S PAPER

ON

NOTES ON SPECIAL SURVEYS OF MERCHANT VESSELS AND TANKERS.

Dr. Montgomerie.

Gentlemen, you have heard an excellent summary of this paper before us. It is a paper that really demands the compliment of being read right through. and I presume that those who speak, whether in criticism or praise, have already read it with great care.

As for myself, I do not propose to criticise it in any way. When I meet a master of his art I only ask questions in the spirit of humility, and I would like to ask Mr. Shaw two questions :—

1. In connection with Fig. 1 at the end of his paper, has he found in his experience that fractures occur more commonly on the inside angle of the tank than on the outside ?

2. Has he found that the requirement of the Rules, which is to the effect that the angles connecting brackets be extended six inches beyond the toe of the bracket in tankers, is sufficient ?

W. Thomson.

Mr. Shaw's paper deals with a subject of supreme importance to Lloyd's Register, and we are fortunate to have placed at our disposal the results of the author's observation and experience.

My own acquaintance with carrying out Special Surveys is small, and I am hardly competent to criticise Mr. Shaw's advice and recommendations. There is, however, one point on which the author's opinion would be helpful to me.

In the course of making investigations into problems of structural strength it sometimes happens that the vessel in question is from 10 to 20 years old. It is not always possible to obtain the exact scantlings from the ship and in such cases an arbitrary allowance requires to be made in the thicknesses used in calculating the stresses. I know, of course, that no rule for reduction in thicknesses on account of age can be given which can be universally applied, but suggested percentage reductions for vessels of different ages which could be used as a guide would be very useful.

J. G. Buchanan.

I wish to congratulate Mr. Shaw for his very practical and useful contribution to our Association.

On page three, under "Drilling of Shell," the author states that the usual position for drilling the shell plating at the ends of the vessel is in the second space abaft the collision bulkhead and in the second space forward of the after peak bulkhead. I know this is the usual practice but I would like the author to explain why these spaces should be selected.

In the older vessels, when outside strakes had diamond doublings fitted at the bulkhead spaces, it was obviously useless to drill in the first spaces, but in the less ancient vessels, I mean those of 24 years of age when drilling is first required, I do not think these doublings are to be found. Any deterioration of the shell at the peak bulkheads would not affect the longitudinal strength of the vessel, but in a general way indicate local weakening, and it appears to me that if this is what is required to be known, the first frame space is the more suitable place to drill because of the extra moisture which can trickle there from the bulkhead plates and so accelerate the corrosion. However, perhaps the author has a better reason for drilling in the second space.

With regard to the fitting of doubling plates which are sometimes necessary on tank margin plates has the author ever considered, when vessels are being designed, the advisability, in order to facilitate repairs later on, of fitting the margin plate with the horizontal flange on top of the tank top plating instead of underneath as is now the general practice?

To effect repairs entails the making and fitting of shaped doublings round the margin knuckle, the renewing and joggling of tank side lugs, the chipping back of the tank side brackets for the thickness of the new doublings and then the existing holes in the tank side brackets generally come too near the heel of the new angles so that new holes have to be drilled in the tank side brackets. Compare all that work with the simple process of cutting adrift and slipping out a margin plate which has its horizontal flange on top and refitting a new plate.

The above arrangement was discussed and adopted in a yard some eight years ago, and, so far as I know, nothing untoward has happened to the vessels so fitted.

C. H. Stocks.

In these notes on Special Survey we have a summary of Mr. Shaw's mature experience, and the paper is a valuable addition to the transactions.

A Special Survey may be considered as having three phases—examination, consideration, and consequent repair. The author duly emphasizes the need for methodical search and he provides a comprehensive list of parts to which particular attention should be directed. Reference also is made to the forms of repair, under each particular section, with notes for guidance. Not so much attention, however, is directed to the considerations which influence his recommendations, except in the tanker section where Mr. Shaw states a basis for permissible reductions.

This intermediate phase—the consideration of and justification for repair—is one worthy of further examination, and it is in the belief that the author lightly touched on this phase so as to provoke comment that one offers something which may encourage him to give us more of his knowledge.

First it is desirable to withhold acceptance of the theory that ship repair work readily comes within the practical knowledge of all, that it is only a process of give and take, requiring some little experience of when to give and when to take. That there is no brief answer to the obvious question of when material should be renewed or at what earlier stage it should be reinforced, only emphasizes the fact that there is more than the factor of thickness to be considered.

Instructions on the subject are general rather than particular; if meagre they have regard for all the circumstances and rely upon a discriminating mind. The reference in Instructions to Surveyors for 2nd No. 3 Surveys to drilling in the "supposed thinnest part" indicates not so much a latitude as, perhaps, appreciation that corrosion and pitting occur on both faces of the plate and that the worst spots do not necessarily come abreast.

What is implied is a sense of values only to be associated with a technical knowledge of the ship structure and experience of what is good and sufficient in relation to original scantlings and minimum values as tabulated. Thickness, whilst being a convenient basis, as basis there must be, is not so conclusive as would permit of the structure becoming a series of patches, without regard to effective continuity. Credited with this technical knowledge and a measure of experience, the Surveyor proceeds

under the controlling guidance of the Principal and Senior Ship Surveyors, and just gets to know the accepted standard without being able to express it in values. Summarised as briefly as can be, and on the lines indicated by the author in the section on tankers :—

Drilled thicknesses, whilst they are a valuable guide, are not in themselves a conclusive basis; the thickness so found will be considered in relation to :—

(*a*) The original thickness and minimum table.

(*b*) The representative value of the drilling in relation to the remainder—whether deterioration is extensive, is in the form of local pitting, or some intermediate degree.

(*c*) The rate of depreciation judged by age of vessel and whether effective protection can be afforded to slow that rate down, i.e., by protective coating or, in the case of tankers, by a change over to less corrosive cargoes.

(*d*) The function of the part in relation to the structural importance of the member.

On some such basis the form of repair will be considered not only from the point of view of making good a local deficiency in thickness but also to ensure continuity of strength in local, longitudinal, and transverse members. "Instructions to Surveyors" gives certain information regarding the drilling of shell plating and from that one may deduce that renewal is to be associated with 33 per cent. reduction in local thickness and that doubling will be necessary when reductions in the aggregate exceed, say, 20 per cent. In the absence of instructions to the contrary this basis may be assumed to be satisfactory for other parts of the structure, subject to adjustment on merit for particular items of which the surveyor on the spot may be the best judge. It is in the application of the above, or any other "thickness" basis, to other parts of the structure that care is necessary, inasmuch as "thickness" is perhaps more strictly applicable to pressure surfaces or to plate members in which stiffness ratio is important; for effective longitudinal material sectional area is implied and in the case of frames, beams, stiffeners, webs, girders, etc. the basis is the combined value of sectional area, strength (modulus) and stiffness (inertia).

The efficiency of a doubling and its attachment may readily be assessed by imagining what the effect would be if the actual portion of material which is being doubled was to be removed, in whole or in part, and principally the doubling left. Similarly for straps and the number and disposition of rivets to ensure equivalent strength in the section. Doublings, as the author points out, are not so satisfactory as renewals, but within the minimum requirements of owners, doublings and semi-renewals cannot always be avoided. An alternative form of stiffening may, in certain cases, obviate doublings. There is a wide range of conditions in deterioration and little latitude can be afforded to repairers to make efficient repairs although surfaces are inferior and spaces are limited. Circumstances, therefore, afford ample scope for a knowledge which embraces rules, interpretations, and first principles, not forgetting that prompt decisions are required during a survey.

Over all, the surveyor is required to make such minimum recommendations as will ensure that, despite a further stage in the process of wear and tear, the vessel will, barring accidents but subject to general attention annually, remain in an efficient condition for a period of four to five years.

On the face of it, the survey of new building might appear preferable; the surveyor there has less variety if a more exacting standard of workmanship to adhere to, but, assuredly, he has less scope for initiative in being provided with precise rules and an extended series of approved plans. In repair work and the survey of existing ships, however, one is spared much of the chase for that elusive ·01 in.

Over an appreciable period on survey work, one notices items of design which could be improved upon to give better service, as for instance :—

(*a*) The subsequent trouble and cost of fitting shoe plates on the stem would largely be avoided by keeping the plate edges farther back and preferably fitting vertical plates useful also in case of stem damage. An equally efficient variation of the furnaced shoe plate consists of two shaped side plates riveted in place and a front plate attached by welding.

(*b*) With reference to sections, it would be preferable that the new standard sections should not be used except on a minimum thickness basis, within regions which suffer severely from corrosion. These new standard sections with a web comparatively thin for strength, have a relatively shorter life.

(*c*) Profiting by the knowledge of parts which on account of corrosion require attention at a relatively early period, some thickness might be added to the structure under boilers and lower half of engine room—both rather inaccessible places for repair without preliminary removals—also coal bunkers. One hesitates to assign a source where this additional material might be found, but if constructive criticism demands a source, one might observe that the flat of bottom shell plating is not frequently a cause for worry on account of corrosion if one excludes tankers and keel plates, and if provision is made for local chafing by cables and protection plates are fitted to take erosion caused by bottom ash ejectors.

(*d*) On tanker work and in way of oil fuel compartments in merchant vessels, a not infrequent difficulty is the prevention of leakage from bulkhead attachments. The use of the tee-bar with its symmetrical section has reduced, if not quite eliminated, the trouble. In theory the rivet in tension is 25 per cent. better value than the rivet in shear, but considering that the rivet in tension is dependent for its efficiency on the formation of the point, the advantage may not be achieved in practice, particularly if an over-zealous caulker in caulking the connection-bar is temporarily forgetful that these rivets have a function not connected with oil tightness. Over-caulking of the connection-bar places an initial stress in these rivet points, which may seriously affect their structural value. The rivet in shear is not so affected and will develop its useful value. Results seem to point to increased riveting in the faying flange and very moderate caulking.

Mr. Shaw makes no special reference to the structure in way of insulated spaces, but these spaces have particular ailments less easy to locate than where the structure is exposed. In particular, one may find appreciable deterioration under insulation in local places on tank top plating adjacent to bulkheads and tunnel, also bilges, deck corners in 'tween decks, and side shell plating due either to defective scupper pipes, leaky brine leads, condensation or faulty thawing down. Ineffective coating of steelwork, prior to the laying of insulation, is also a contributory and less anticipated cause.

Structural repairs being more costly owing to necessary removals, opportunity should be taken whenever insulation is opened up to examine for wastage, and to advise the carrying out of repairs to plating and riveting at that time, although the Special Survey may not be due. A case in point was the opportunity to renew a considerable number of shell rivets suffering from point pitting, coincident with renewal of insulation following minor fire but major water damage.

Having recently had two North Atlantic trips during the winter period looking for heavy weather conditions—with some measure of success and due appreciation of the opportunity—I can commend the need, stressed on various occasions, for care with those items covered by the comprehensive phrase "closing appliances," also steering appliances, their protection and spares.

A. Urwin.

It is a great pleasure to me to see Mr. Shaw here tonight.

In his excellent paper Mr. Shaw states a number of very sound principles. There is the question which arises at almost every docking, namely, should the indented plating be listed. ? The suggested criterion for dealing with this is a good general rule. The elimination of hard points from the plating, the need of thorough examination of riveting in peak tanks, the superiority of part renewal as against the practice of fitting doublings, the advisability of fitting gussets rather than relying on increased margin lug riveting, the need for caution at examinations prior to Special Surveys and making clear that opinions given are not final at this stage—these points, I think, are all very sound and worthy of emphasis.

The question of whether all cleaning and coating should be dealt with at the Special Survey or a part left to be done by the crew on ballast voyages, is one that often arises, and Mr. Shaw states that provided there is no heavy scale this might reasonably be allowed. While in general agreement with this, every effort should, I consider, be made to get the work done at the time of the Survey. There is a type of mind greatly influenced by appearance, and the opinions they voice can give a ship a bad name and cause misconception to arise as to the true state of the structure. Evidence at the recent inquiries into lost ships might be quoted as illustrating this point.

Where an engine-seating has worked loose it is advisable to look carefully at the original workmanship. This work is often drilled to ensure fair holes, but, unfortunately, sometimes marred by the holes being left with insufficient countersinking to get the full clamping power of the rivets. With such work, and oil finding its way between the surfaces, a very slack seating can be the result.

Mr. Shaw has mentioned a standard of permissible wastage for tankers. The great difficulty is putting a correct value on the wastage because a few thicknesses have to serve as representative of large areas. This calls for good judgment and arduous labour in picking out local wastage. With regard to bottom shell wastage in tankers, the run of the oil to the strums appears to be the main location, the pitting and grooving in the spaces adjacent to the bulkheads getting worse as the strum is approached.

W. Watt.

Gentlemen, I am not going to take up much time tonight, and I will endeavour to keep to my allotted three minutes, but I do want to compliment my old friend, Mr. Shaw, on this very complete paper. He has always shown a keen interest in the work of the Staff Association, and he has given us a further demonstration tonight of that interest, although no longer on active service with the Society.

As I agree with practically all he has to say and all he has stated in the paper, I will confine my remarks to one or two little points with which I cannot exactly say I am in complete agreement.

In the middle of page 1 Mr. Shaw refers to the practice of the Society prior to 1906, and says that "owing to the restriction as to the depth of vessels, they were designed and built with light scantling superstructures, three of the types being awning deck, spar deck and partial awning deck." Now, that restriction was not placed because the vessel was a single-deck ship, because light superstructures were fitted when there were two or three decks, and, as a matter of fact, we had started on heavy topsides before 1906. There was a restriction as to the depth of a single-deck ship, but that was not the reason why the topsides were made of a light scantling.

Then on page 2 he refers to the question of the treatment of fractures. Mr. Ward has already spoken of that, but I should like to add a word or two. Some fractures are serious and deserve to be noted and watched, but I would like to call your attention to a little fracture I had a deal to do with in the case of the inquiry into the loss of the "La Crescenta." In about 1928 the surveyors reported that a certain plate at the end of a web frame bracket was fractured and had been electrically welded. The welding was examined a year later and also at dockings since then until shortly before the ship's loss the surveyors recommended that the "condition" should be removed, but Mr. Ward wanted another examination before agreeing to this. During the inquiry I found out that the fracture was only two inches long, and when cut out and welded up the welding only extended over three inches. Surely a fracture of that length is hardly worthy of mention in the Special Reasons List or even the surveyor's report ?

On the top of page 5 Mr. Shaw refers to the British Standard profile and suggests that the wastage of webs in bulb angles is less since the introduction of this standard. I can hardly understand that suggestion, because the web of the British Standard section is much thinner than it used to be, and as corrosion must be taking place on both sides, it seems to me that the percentage wastage in that particular web, even under the lower edge of the bulb, must be greater than was the case in the old-fashioned bulb angle which had a much thicker web.

One other matter—on page 7—the author deals with hatch covers. We have this matter under consideration at the present moment, and I do not think I am giving anything away when I say that very shortly there will be more complete instructions issued in regard to hatch covers and closing appliances generally, and you will probably find that all covers will require to be examined in place.

In the last paragraph of this particular section Mr. Shaw speaks about the quality of timber, and in the last line of the previous paragraph he mentions that the maximum shrinkage due to temperature is about a quarter of an inch in a two and a half inch cover. I think he must have gone astray in that figure of a quarter of an inch.

About five or six years ago I purchased some small pieces of wood, for quite a trivial purpose, but one piece was so green and full of sap that even for the unimportant job for which it was intended, I rejected it and put it aside. We were dealing, about that time, with the question of hatch covers and

shrinkage, so I planed this piece of wood, marked the dimensions on it and put it away. The wood was of U.S. No. 5 quality—this is one of the qualities Mr. Shaw suggests is unsuitable for hatches, and I quite agree with him, but that is not the point I am driving at. What I want to make clear is that it was a very poor quality piece of wood quite unsuitable for any purpose where shrinkage could not be permitted. This piece of wood was placed in a dry shed and remained there for a long time and for the last two or three years was in the vicinity of a kitchen boiler.

I recently measured it again with the following result :—

	Original dimension	Present dimension
Length	4 ft. $1\frac{1}{4}$ in.	4 ft. 0·85 in.
Width	10 „	9·66 „
Thickness	$2\frac{7}{16}$ „	2·37 „

The timber to-day certainly looks better than when I first saw it but I should still say it was unsuitable for hatch covers.

Now if a green piece of wood with plenty of sap in it shrinks only $\frac{1}{16}$ in. in the circumstances just described I feel that Mr. Shaw has gone a little astray in saying that the maximum shrinkage due to temperature is about one quarter of an inch in a two and a half inch cover. This shrinkage represents two feet in a hatchway 20 ft. wide. Further, as the rules require sound timber the strength of the cover would be that of a two and a quarter inch cover and not that of a two and a half inch cover.

R. L. J. Ward.

I am sure we are all much indebted to Mr. Shaw for his interesting and instructive paper, which will be a valuable addition to the Transactions of the Association.

The results of surveys of ships built and classed since the introduction of the Revised Rules indicate the value of the additional provision there made against local wastage in boiler spaces etc., the decrease in the numbers of fractures of the shell plating as a result of the omission of brackets to shell plating at bulkheads and the advantages arising from the simplification of the structural arrangements, e.g., the dispensing with web frames and side stringers etc., in the conservation of the hull structure.

A main cause of such fractures is, undoubtedly, the existence of a rigid point, e.g., a bulkhead bracket in a surrounding area of structure which is relatively flexible. The resultant concentration of stress almost inevitably induces fracture of the shell plating at or near the extremity of the bracket.

The remedy appears to lie in the provision of increased thickness of the shell plating and the suppression of " stiff " points wherever practicable.

Completely effective remedies against panting fractures and fractures or leakages of margin plates and their connections are still to be found.

Fractures in shell plating are generally repaired by electric welding, and, if slight, further examination of these repairs is not generally recommended, but more important fractures, unless also repaired by doubling, are usually recommended to be further examined.

With regard to wastage in tankers, some exceptional cases in recent years have been noted.

In one case, at a First Special Survey No. 1, extensive pitting of bottom shell plating and bulkheads to the extent of 75 per cent. of the original thickness was reported, particularly in tanks used for water ballast.

In another tanker very extensive renewals were necessary at the First Special Survey No. 1 to the upper plating and stiffening of longitudinal and transverse bulkheads and expansion trunks.

In the cases of tankers engaged in the carriage of white oils, as Mr. Shaw indicates, change of service at an early age from the carriage of white to heavy oils appears advisable if renewals and repairs are to be kept within moderate limits.

With regard to the drilling of the shell plating, it may be of service to surveyors in more distant ports to observe that when results of drillings are forwarded for consideration they should be representative of the *average* thickness of the plating amidships or at the ends of the vessel, and should

not include results of drillings taken in locally wasted or pitted spots, which are misleading unless the restricted area of the wastage or pitting is made clear. Where considerable wastage is confined to the parts in way of the bunkers, further drillings clear of these spaces are a necessity in order that the extent of repair or compensation may be correctly determined.

It may be added that, as it is the practice when considering the results of drillings to take account of the Present Rule requirements as well as of the original thickness, it is found to be seldom or ever necessary, in the cases of ships built prior to the adoption of these Rules, to require the doubling of a strake of shell plating over the midship part of the vessel's length.

(Mr. SHAW replied briefly to the points raised.)

DR. MONTGOMERIE.

Gentlemen, you have heard Mr. Shaw replying to the various points raised, and you can now estimate the loss the Society sustained when he departed from us—that is to say, from his active life among us.

I think that loss is now mitigated to a certain extent by the fact that this compendium of his experience is to be put in print, for it will now be in such a form that we all may benefit from it. His paper will be particularly valuable not only to those who have been here tonight but to those of our number who are scattered all over the world, and I am sure it will be read carefully by people who know Mr. Shaw only by name.

I ask you to give him your hearty vote of thanks for his paper.

CORRESPONDENCE.

S. T. BRYDEN (London).

The perusal of Mr. Shaw's interesting paper almost inspires a desire to return to the outports to take part in the romance of a "number three." The only point upon which I would venture to offer a suggestion is that of the importance of the examination of the pipes of overboard scuppers and sanitary discharges where they pass through holds, because in case of wastage or damage to the pipe, the storm-valve which is usually fitted at the ship's side would not suffice to check the inflow of water into the hold.

C. BARTLETT (Sunderland).

The Staff Association undoubtedly enhances the value of its proceedings by incorporating work from retired members of the Staff. Years of valuable experience must surely supply material for an interesting and instructive paper, and in this case the result confirms the supposition. We have under discussion a concentrated encyclopædia of ship repair surveying, and the following remarks are therefore principally amplificatory in character.

Dealing with boiler room tanks on page five, the author says :—"Fitting doubling plates, except in way of local wastage, is rarely a satisfactory job."

With this statement there can be nothing but complete agreement, but, in my opinion, it might be applied more generally to all parts of the vessel, and not solely to the boiler room tank. Doubling is almost invariably a poor and an uneconomical repair and one to be avoided unless renewal is impracticable either on account of difficulty of access or of excessive cost. One exception to this general statement may be the case of a slight fracture in a shell plate otherwise in good condition.

A personal experience may be quoted in this connection :—A vessel undergoing survey had the deck stringer plates on both sides doubled for a considerable length at the previous survey. During the four years corrosion had taken place between the original stringer and the doubling at a rapid rate, and both had to be removed and a new stringer fitted.

Doubling as a repair to decks, watertight bulkheads or tank tops is difficult to carry out efficiently owing to the unevenness of the old material and the existence of countersunk holes in the same.

Concerning the reinforcing of wasted bulb angle frames in smaller vessels, it might be suggested that the character of the repair considered desirable should bear some relation to the age of the vessel. In colliers general wastage of the webs of the frames is frequently found in vessels twelve years old. In such cases it is generally confined to the first 10 or 15 frames abaft the collision bulkhead, where the shape of the ship and the width of the hatch expose the frames to the action of the weather. Reinforcing wasted frames is a repair which has a relatively short life, and owners would be well advised to renew the frames if it is desired to retain the vessel in service beyond the subsequent survey. The cost of renewal is approximately 50 per cent. greater than the cost of reinforcing, and in colliers and small vessels with relatively large hatches the life of the latter repair is roughly four years ; the rest of the argument is a question of simple proportion. Regarding the author's remarks on this subject of reinforcing on page 5, paragraph 1, is not the last sentence somewhat ambiguous ?

Mr. Shaw has drawn attention to the necessity for care when dealing with deck plating covered by sheathing or composition. In one vessel put through a first No. 3 survey recently, the forecastle deck plating was badly pitted beneath the wood sheathing, and in another ship going through the same survey the steel deck under the composition in a large saloon house on the shelter deck required extensive repair due to pitting. It is not suggested that these cases are exceptional ; they are simply quoted to emphasise the necessity for caution.

In conclusion, I desire to thank the author for a most helpful and instructive paper, suggesting at the same time that a complete series would be greatly appreciated ; the series to consist of a paper similar to the one already written on new construction, and, if the Censors would permit, a dissertation on the technique of diplomatic contact with the Society's clients, including a few remarks and anecdotes concerning the "old-timers," both Superintendents and Surveyors.

G. R. Edgar (Greenock).

The Association should, I think, consider itself fortunate in being the recipient of the conclusions of the author's ripe experience, than which few contributions could be more valuable. He is able to look back over considerable changes both in the general type of work and in the details of special surveys—changes which have been for the most part gradual. The future will probably show equally as much, and possibly more, divergence from past conditions now that the vessels built to the Rules introduced in 1922 represent a large and continually increasing proportion of the whole and that electric welding has recovered from the false start of 1919. Mr. Shaw has so well covered the ground that comment must be restricted, but out of the many points which arise some appear of especial interest.

Doubtless others will draw the author's attention to the recent alteration in the wording of the Rules giving the requirements for Special Survey No. 3 in respect of lifting of ceiling. With regard to the removal of rust the position is unaltered, but option is allowed as to the extent of lifting of ceiling. The onus is, however, clearly put on the owners' representatives to show that the steelwork is "in good condition, free from rust and coated" before the lifting of the remainder of the ceiling may be dispensed with. If, for example, the ceiling has been up only a short time before the Special Survey, say at a damage survey, and the steelwork below is thus in the condition stated, it is clear that the lifting of the whole of the ceiling and replacing it serves little useful purpose. It is to give this option only that the alteration has been made ; normally it will need to be lifted as in the past.

The introduction of the new Rules after 1922 resulted in a redistribution of longitudinal material to a certain extent, more being concentrated on the decks and less on the shell. The thickness of the strength decks between the hatch side coamings and the gunwale is adjusted to give a sectional area of material of the standard of the Rules and may very well differ, and generally does, from any tabular thickness. In fair-sized vessels a substantial thickness may still represent a substantial reduction in strength, and, in view of the relatively greater importance of this continuous deck material, it is advisable when wastage has taken place to refer to the plans or reports for the original thickness. The drilling of the deck plating has thus assumed an added importance.

With regard to the gradual set up of the bottom of small coasters, to which Mr. Shaw makes reference on page 2, this is often found in this type of ship where no strengthening over the Rules has been introduced. I think it is extremely doubtful whether any good purpose is served by attempting the

relatively costly repair of only repairing the bottom, and I hope Mr. Shaw will agree with this. And at the same time to introduce additional stiffening in a vessel which has done without it for years is also a proceeding which requires a good deal of justification. In my opinion, if the set up is of limited extent and gradual, the riveting on examination, so far as can be found, sound and no fractures or buckling in the bottom framing discoverable the bottom is better left alone. But while a set up of say one inch over a considerable length may thus be permissible, the same set up on a shorter length would indicate damage needing attention. I think in this matter the type of vessel and the conditions under which she works should be borne in mind, and regard paid to the ultimate object in view and to the views of the owners. With these cases the condition of the frames where they leave the floors at the upper turn of the bilge is illuminating.

Mr. Shaw uses an unusual term on page 3 in referring to a "bible" plate—would he kindly explain it?

Reference is made on page 7 to the examination of wood hatch covers not in place. It may be possible with special precautions of an abnormal nature to do this, but there are many cases met with where, in my opinion, it is entirely inadvisable, having regard to the great chance of error and to the importance of the matter.

No one would deny, particularly after recent events, the importance of the survey of steering chains, but I should like to ask Mr. Shaw to what extent is it the practice to retest chains after repair.

In some ports there are no facilities for testing, and it need not be concluded that because a repair has not been tested it is necessarily inefficient. Tested chain should, of course, be used, and the number of welds reduced to a minimum, but even if sent to a proving house for repair and test, the weld has there to be made by the smith, and care can be taken with the welds by the smith at the repair works. I do not know what evidence there is to show that failures in steering chains have occurred at recently repaired links, and, if this has not been demonstrated, is it not more likely to have occurred in some worn part that has not been repaired? I am glad Mr. Shaw draws attention to the undesirability of the so-called annealing by passing the chain through an open fire.

One of the most unpleasant and most difficult items involved in surveys of recent years is that of assessing the extent and importance of the corrosion of the inner surface of the bottom plating, and of the rivet heads resulting from the carriage of oil fuel in the double bottom tanks. This may be severe and require attention as early as No. 2 Survey, though one is always assured there is none. As referred to by the author on page 9, the same feature appears on the bottom plating of oil tankers in widespread patches and in pitting. It is often not easy to arrange for a careful examination to be made while other repairs are proceeding, but in view of the considerable extent to which the wastage may have gone it should not be overlooked. In one No. 3 Survey, on a tanker of a little over 400 feet in length, carrying spirit, there were extensive patches in the wake of butts of bottom shell and adjacent to seams found to be down to $\frac{5}{16}$ ins. and just over.

I am glad to have had the opportunity of reading Mr. Shaw's paper, which I have done with much benefit and interest.

N. Turnbull (Newcastle).

If, as the author states in the last sentence of his paper, "there are many points of interest not touched upon in this paper," we may console ourselves with the large number and variety of points of interest which he has so clearly and so ably dealt with.

Before making any recommendations for repairs to an old vessel coming under survey, much may be learnt by a careful study of the reports of previous surveys, followed by an examination of the repairs then effected in order to ascertain in what manner and to what extent the hull has already been dealt with and whether the previous repairs have been entirely satisfactory.

The handling of the case by an experienced surveyor can, after a time, be easily detected, as the repairs will be seen to have been carried out on a system which, with a view to future repairs being necessary, can easily be extended to other parts of the hull, and, further, permits of intermediate strengthening being introduced in an economical and practical manner, so that when completed the later repairs will simply appear to be part of the original scheme.

Difficulty in devising easy and economical means of effecting repairs can, however, be the result of the method of construction of the vessel, not having been designed with a view to facilitating future repairs. It is desirable that before detailed recommendations are made, a general idea of the condition of the hull structure as a whole be formed, as it is upon such a knowledge that an efficient scheme of repair should be based.

In a compartment where there is heavy scale and general wastage, the use of a hand hammer and, if necessary, judicious drilling, will enable a decision to be reached as to whether scaling the compartment throughout for further examination is desirable, or whether certain wasted material be immediately condemned for renewal. Recommending a compartment to be scaled throughout, and subsequently condemning a large part of the scaled material to be renewed, should be carefully avoided wherever possible.

In addition to the necessity for the general efficiency and strength of the hull structure being maintained, there are also the questions of the satisfactory means of closing all openings in bulkheads, weather decks and superstructures, and the efficiency of the steering arrangements. Special attention should be given to the supports of hatch covers, it being occasionally found that the hatch beams have dropped slightly through wear and being forced into place, thus resulting in there being no bearing for the wood covers at the intermediate beams or side fore and afters. When the wood covers are in place it is easy to have a few removed in order to see whether the others are being properly supported.

The author specially refers to the necessity of the rudder, when in dry dock, being placed amidships and the alignment of the quadrant checked. This is most important, as a twisted rudderhead may in this way be readily detected. A case came under notice some time ago where, on removing the keyed tiller which was out of alignment, it was found that the tiller arm was fractured on each side of the fillet at the boss, also that the rudderhead itself was twisted and fractured in way of the deck stuffing box, necessitating the renewal both of tiller and of rudder stock.

On account of excessive corrosion of the tank top plating under the boilers, it may be decided instead of renewing the tank top plating, to provide the necessary strength by rider plates and other means, leaving the space with open floors and cutting it off from the water ballast tank system. It should be noted, however, that such an arrangement is inadmissible in a vessel of 330 feet in length and over, which holds a Board of Trade Passenger Certificate, as the sub-division regulations required in such cases that a double bottom tank be fitted from peak bulkhead to peak bulkhead.

REPLY BY THE AUTHOR.

Before replying to the discussion, I should like to correct certain errata in the paper :—

At the top of page 3, the full stop after "bracket" should be deleted and the sentence ended at "eight years old."

Figure 1 should be designated "A" and Figure 2 "B" and "Tanker" deleted in both instances.

Dr. Montgomerie.

As stated in the paper, fractures in the connecting angles on tank flange plates are not common. In recent years I have found more failures on the inside bars than on the outside. The extent of the fracture is greater on the inside, in some cases extending for the full depth ; in the outside angle the fracture rarely extends beyond the third rivet from the top. I have, however, seen cases where the bar was removed in two pieces after the rivets were drilled out.

Ordinarily the extension of the connection angles six inches beyond the toe of the bracket has been found sufficient on small brackets.

Six inches, in my opinion, should be considered a minimum extension, and increased on large brackets.

Special reference is made in the paper to vessels with transverse framing in conjunction with strong longitudinal members ; in these cases six inches has, in many instances, not been sufficient, and in

effecting repairs the angle has been extended six inches beyond the adjoining bulkhead stiffener. In the case of vessels with two longitudinal bulkheads, it has been found necessary to extend the connection angles on the bracket in way of the middle transverse beyond the shelf plate fitted on the wing side of the bulkhead.

W. Thomson.

For the purpose of arriving at the structural strength of a vessel I suggest the following basis for the average reduction in the thickness of deck plating: one-twentieth of an inch at eight years old, two-twentieths at fourteen years, and three-twentieths at twenty years; the latter reduction would only apply when the original thickness was over half-an-inch. In the case of original thickness of half-an-inch and under, a reduction of three-twentieths would entail renewals at the respective surveys and the average reduction would not exceed two-twentieths of an inch.

J. G. Buchanan.

To conform with the minimum requirements of the Rules three holes must be drilled in each strake of plating not covered with cement, the positions indicated being about amidships and in the vicinity of the peak bulkheads. The exact position is not arbitrarily fixed, and will necessarily depend on the condition of the plating, the primary consideration being to obtain the average thickness of the plating. Additional holes should be drilled in all plates which show signs of local wastage.

Repairs and/or Renewal of Tank Flange Plates.—The fitting of the horizontal flange of the margin plate on top of the tank top plating instead of the usual practice underneath, has been adopted in a few instances, and I see no objection in this method from a structural point of view. When discussing this question with builders, they pointed out that the tank top plating is punched from loft templates, with the exception of the outer strake, which is templated from the ship, and that the plating prepared in advance is used to the exclusion of ribands in securing the floors in position, also they preferred to have the spaces adjoining the flange left open until the adjustment of the floor end bars and tank flange is completed. With the flange outside, plates could undoubtedly be more readily removed; as against this, the increased thickness obtained by fitting doubling plates increases the inertia of the plating at least 400 per cent. in the vicinity where failure occurred, and this, in my opinion, is one of the cases where the fitting of doubling plates is justified.

C. H. Stocks.

Mr. C. H. Stocks, in his comprehensive remarks, raises many interesting points and particularises certain phases of survey work, on which further views would be appreciated, and I will endeavour to deal with some of them.

It is impossible to give a working basis for permissible reduction in thickness which may be applied to all parts of the structure.

The permissible reduction cited by Mr. Stocks, given in "Instructions to Surveyors," is intended to be a general guide for shell plating. The reduction allowed on the oil-tight bulkheads, of which particulars are given in the paper, ranges from 25 per cent. in the thinner plating to 30 per cent. in the bottom strakes, and I suggest these figures for general application.

As a general principle it is a more satisfactory job to renew material rather than fit doubling plates. The economic aspect, however, must be considered, where the renewal entails extensive and costly removals to effect the repair.

In the case of local failure of material, the fitting of a doubling plate in conjunction with welding the fracture is often more efficient than renewing the plate of the original thickness, as increased inertia is obtained where needed.

I agree that the more general adoption of fitting tee bars is desirable in oil ship connections; in many cases of repairs angles have been replaced by tee bars.

I do not agree that new building calls for a more exacting standard of workmanship than repair work; the latter undoubtedly gives greater scope for initiative and the application of experience. The question as to whether the survey of new ships is preferable depends upon the inclination of the individual surveyor; in many cases it is "Hobson's Choice," and in my opinion surveyors should consider themselves fortunate if they are allotted to a district which includes both old and new work.

Insulated vessels were purposely excluded from the scope of this paper, and I have read Mr. Stocks remarks on this special type with great interest.

W. Watt.

I am pleased that Mr. Watt failed to carry out his intention to limit his remarks to the allotted span of three minutes for discussion, as all the points raised by him are interesting.

With regard to the change that took place in the design of vessels, after the removal of the restriction of a maximum moulded depth of 23 ft. 1 in. to the first laid deck, the cargo type of vessel with awning, part awning or spar deck gradually disappeared and was replaced by the single deck type with short erections, designed to obtain the necessary cubic capacity in the holds under the deck, to the exclusion of 'tween decks. Only the surveyors who have put the respective types through survey will appreciate the marked diminution of renewals at an early age, which ensued on the deletion of continuous light superstructures.

I am in entire agreement with the remarks relating to the "listing" of electric welding; discrimination, if wisely exercised, would remove some of the anomalies which continue to exist in this connexion. I have spent hours in trying to find some of the welds, and in some instances have failed to locate them.

The wastage referred to in bulb angles which entails renewals is local at the concave part of the bulb on the inner side of the web, and is due to the unsatisfactory scaling at special surveys in this vicinity, owing to the curvature of the section. The modern standard section has a flat surface which presents no difficulty in removing the scale. I may remark that the wastage on bulb angle sections is greater on the inside of the standing flange than the outside.

Hatch Covers.—I agree that it is essential that all covers and supports should be examined in position; this, in some cases, can only be done after the repairs in holds have been completed, as the supports have been removed to facilitate the progress of the work. My remarks relating to the checking of the length with a batten was suggested with a view to ascertain the number of new covers required in cases where fore and afters are fitted; more covers are condemned owing to shrinkage in length than to any other defect. The shrinkage in thickness I quoted was for a $2\frac{1}{2}$ in. cover, which in practice is not more than $2\frac{7}{16}$ in. dressed, therefore the actual reduction when $2\frac{1}{4}$ in. thick is $\frac{3}{16}$ in. (in the paper it is given about $\frac{1}{4}$ in.) In the sample for which figures are given by Mr. Watt the reduction in volume is 7 per cent.

Shrinkage from green to oven dry is 11·5 per cent., and at a liberal estimate the temperature in a kitchen would not exceed 90°. The hatches on a vessel when going through the Red Sea would be subjected to a temperature of 120°, therefore the rise of temperature encountered in the respective cases would be, say, 60° to 90° and 60° to 120°. It would therefore appear that the reduction stated in the paper is not over-estimated. In this connexion it should be remembered that seasoned timber does not re-absorb moisture.

The strength is dependent on the moisture content, the rupture modulus for timber or hatch cover quality seasoned in a temperature of 60° is about three tons, and 120°, 3·75 tons; the strength computed on this basis would be slightly in favour of the $2\frac{1}{4}$ in. cover.

Bearing out the foregoing, in quite a number of cases measured at the time that the new freeboard regulations came into force, the covers were found $2\frac{1}{4}$ in. thick on vessels trading to the East.

In the case of vessels trading in home waters, the thickness was very slightly reduced, except by wear.

R. L. J. Ward.

Apropos of hard points, mentioned among many other interesting points in Mr. Ward's remarks, some years ago, in the case of a fracture in a shell plate at the toe of a bulkhead bracket, I recommended that a shell doubling plate be fitted, two spaces long on each side of the bulkhead, and the bracket be removed. At the next survey the same shell plate was found fractured at the toe of the bracket, which had been fitted to an extended length of three spaces, on the instructions of the owner's superintendent.

The exceptional cases mentioned of corrosion in tankers at First Special Survey No. 1, directs attention to the necessity of thorough examination at all surveys.

The remarks and explanation relating to the drilling and recording of the thicknesses of shell plating, together with the basis on which thicknesses are considered, should remove some anomalies which have existed in this connexion.

A. Urwin.

Mr. A. Urwin directs attention to the necessity of deep countersinking in engine seating plates; more slack rivets occur through the horizontal flange of the continuous angles connecting the top plates than in any other part of the seating, or, proportionately, than in any other part of the ship, and I should like to emphasise that the trouble is mainly occasioned by attempting to finish the rivet with a flush point.

The decision as to whether all cleaning and coating should be done at the time of survey is, of course, dependent on the condition, and if scale exists to a degree which might reasonably cause a misconception to arise as to the state of the structure, I would certainly recommend its removal.

I cordially endorse Mr. Urwin's remark that good judgment is required in dealing fairly and satisfactorily with the structure of an oil ship, and to do so the labour is indeed arduous.

S. T. Bryden.

I have to thank Mr. Bryden for directing attention to a very important point in surveys, which is omitted from the paper, i.e., the examination of the pipes of overboard scuppers and sanitary discharges. The deletion of "almost" would introduce a new phase of thought in connexion with "number threes."

C. Bartlett.

I am in general agreement with the views relating to doubling plates, and in this connexion would emphasise the point regarding the difficulty of obtaining sound workmanship in way of countersunk holes. The usual method adopted, i.e., rimering the holes a size larger and extending the countersink, even when executed with great care, is not perfect.

Regarding repairs to bulb angle frames, I would not recommend reinforcement unless it was considered that it would remain effective for a minimum period of eight years. The chief objection of owners to renewal of the section is the time the vessel has to be in dry dock to carry out the work. In explanation of the last paragraph in the paper on this particular subject, I have seen cases where the reinforcement has been unnecessarily extended over the tank brackets and beam knees, when the frame was not wasted in this vicinity.

G. R. Edgar.

I am indebted to Mr. Edgar for drawing my attention to the recent alterations in the requirements of the Rules in respect to lifting of ceiling at No. 3 Special Surveys. I agree that from Special Survey No. 2 onwards, it is desirable to have the original thickness of decks before deciding on the extent of renewals where wastage is apparent.

With regard to the remarks in connexion with set up of the bottom of small coasting vessels, it must always be remembered that the owner is entitled to have the vessel placed in a similar condition as before the damage occurred. The extent of the set up must also be considered in relation to the question of safe dry docking.

In all cases I have suggested the advisability of fitting additional stiffening in some form, and fairing the bottom only when necessary. Buckling of the frames at the upper turn of the bilge is a common feature, the term "illuminating" is an apt description. The buckling is most pronounced in cases where the floors have been increased in depth with no turn up at the bilge. As brackets in this vicinity are objectionable as regards the stowage of cargo, the usual practice is to fit reverse bars extended down the floor.

Bible plate is a term used in the North of England, and is synonymous with stem shoe plates.

Steering Chains.—Retesting of chains after part renewal is now common in districts where testing machiners are available for the purpose. My experience of latter years does not include districts in which such facilities do not exist. New chain is made by expert workmen who are continuously engaged in this class of work, and at all testing establishments the renewals are made by an expert workman kept for the purpose. At repairing establishments the work is done by a blacksmith, and is intermittent, and it would appear desirable that the work should be done by an expert.

I understand that a patent link, secured by a screw, is now obtainable, and has proved satisfactory in service.

The practice recently adopted by many owners of carrying a spare length of chain, long enough to replace any of the lengths on the ship, appears to be the most satisfactory solution of the difficulty.

N. G. Turnbull.

The remarks relating to condemnations being possible in many instances without putting the owners to the expense of scaling are particularly applicable to oilers.

Mr. Turnbull draws attention to the necessity of foresight being exercised when deciding the scheme of repairs in relation to ensuing work at subsequent surveys, a most important point which, in some cases, appears to have been overlooked, especially in dealing with sectional material.

It is essential that consideration should be given to the probable condition at the next special surveys and the extent of renewals required, in many instances the renewal of part of the material, as against reinforcing all of it, is a preferable and more economical method of repair, and may be readily extended as occasion requires.

The reminder that it is inadmissible to alter the double bottom tank in way of the machinery space to an open tank, in a vessel 330 feet in length or over, which holds a Board of Trade Passenger Certificate, may prove useful; I must plead guilty to ignorance on this point.

In conclusion, I should like to tender my appreciation of personal references, and to heartily thank all those who have been good enough to criticise and enlarge the interest of the paper by their contributions.

NOTES ON VARIOUS TYPES OF DREDGERS AND BARGES.

By M. MACLEOD.

Read 9th January, 1936.

I propose for my subject to deal with an aspect of Shipbuilding out of the usual run, that of small craft, and although to the average man small craft get little serious consideration, nevertheless, I submit that the subject matter of this paper is of primary importance, as upon these craft depend the prosperity and success of all our harbours, river waterways, and Maritime Corporations. Indeed the useful existence of most harbours depends upon and has been created by the craft I now wish to describe, viz. :—

Dredging Craft.

The characteristics and forms of these craft are so varied that I can only dwell on the fringe of the subject, and describe to you in a brief manner some of the types commonly used to make and maintain sufficient draft of water to permit the linking up of sea and inland traffic.

Dredging Craft may be broadly stated to be of two classes, viz., the "Bucket Class" and the "Suction Class."

The term "Bucket" obviously refers to a machine which removes the material or "spoil" by means of buckets which, after obtaining their load by biting or digging into the bottom, are raised clear of the water and discharged either into a self-contained hopper or a waiting barge, or upon spoil banks, whereas a "Suction" excavates by direct centrifugal pumping through suction pipe, pump and discharge pipe into a hopper contained in the dredger itself or into hopper barge alongside, or into adjacent deep water or prepared reclamation reservoirs, from which the great volume of water necessarily pumped along with the dredged material runs off, leaving a deposit of solid matter.

The Bucket Class are of three types, viz. :—The Grab, the Dipper, and the Bucket Ladder.

The Grab and Dipper Class have a single bucket each. In the former the bucket is suspended from the end of a swinging boom or crane, and consists of two or more jaws or shells, by the closing and opening of which the bucket is loaded and discharged, while in the latter it is a "scoop" attached to a long girder arm and "digs" in the same manner as the familiar steam "Navvy" or shovel used on land.

The Ladder Class consists of a series of smaller buckets travelling in endless chain succession upon an inclined frame called a "Bucket Ladder," in passing under the lower end of which they receive their loads by scraping along into the bottom, and on reaching the top they discharge into a shoot while passing over the top of the tumbler.

The above dredgers may again be subdivided into three classes, viz. :

1. Stationary dredgers ;
2. Self-propelled barge loading dredgers ;
3. Sea-going dredgers.

The first type is usually engaged in rivers, harbours or in calm waters, and is fed laterally or radially by means of anchorage and hauling cables or "spuds," discharging either into a waiting barge or into deep water or spoil basin more remote from the dredger. These vessels are usually rectangular in form and of box section with sloping end at stern for towing.

The second and third types have ship-shaped hulls and sea-going qualities. The second, because of the accompanying hopper barge, is usually confined to the calmer water of rivers and estuary channels, while the third is a sea-going vessel, comprising hopper barge and dredger in one, discharging her own spoil and usually engaged at mouths of rivers, a short distance from her dumping ground.

After this brief summary of types of dredgers, I will now take the commonest type seen in this country, viz.:

The Self-Propelled Bucket Barge Loading Dredger.

To understand these, one has to consider the work to be done, such as lifting and shifting of spoil, and a conveyor system appeals as the most economical method of carrying out the work. We are led then to consider how such a system can be easily applied, and first of all, therefore, we take an endless chain of buckets supported by a rigid girder to act as a conveyor, of a sufficient length to reach the required depth at an angle of, say 45°.

This girder is called the "Bucket Ladder." Now to fit this girder to a ship and to control it the hull has a longitudinal well, formed from the end of the vessel to about amidships, through which the ladder can be raised or lowered as required. The length of the well is generally arranged so that the ladder when raised is wholly within the well.

To support the ladder a steel trestle is built amidships, called the "Main Framing" which, on bearings at top of frame, takes a shaft through the top end of the ladder; this centre becomes a radial point about which the ladder alters its angle of declivity.

Behind the bucket ladder top pin and on the same level a second shaft is fitted on which is mounted a four or five sided barrel called the "top tumbler," and on the lower end of the bucket ladder there is fitted a five or six sided barrel called the "bottom tumbler."

The bights of the bucket endless chain are kept taut between these two tumblers and pass round them. The loaded buckets are supported on the top side of the ladder by rollers and the empty buckets hang in a catenary curve below the underside.

At the end of the vessel another trestle, called the "Fore" or "After Framing" (according to which end of the vessel the "well" is formed) is built, from which, by means of lifting ropes and pulleys secured to the lower end of the ladder and to pulleys on the top of framing, the ladder is lowered or lifted to vary the dredging depth.

Thus we have a conveyor bucket ladder mounted on a vessel ready for work, but minus the power.

This problem is easily solved, as when the dredger is "working" the vessel is stationary, and consequently the propelling engines are idle.

The propelling machinery can, therefore, be utilised by disconnecting the propeller shaft from the main engine by a clutch, and by means of shafting and gearing, or "belt drive," the power can be transmitted to the top tumbler, and thus we have in a general sense a workable bucket dredger.

We are now in a position to go into further detail, and I propose to give you an outline description of a

Steel Single Screw Barge Loading Bucket Dredger. *See* Figs. 1 & 1a.

This vessel's hull is of ship form with an open well in the middle at the fore end in which the ladder moves. The watertight compartments on either side of the well are used for the accommodation of the crew, storerooms, workshops, and hoisting engine room; the compartments aft of the well are for bunkers, engines, boilers and tanks as in ordinary sea-going vessels.

The sides of the hull are well stiffened by wood fenders and beltings fitted at deck level and at the waterline, so as to guard against damage that might occur through hopper barges bumping against the hull whilst loading alongside. Strips of heavy plating are fitted to the well sides to guide the bucket

ladder and at the same time to protect the well side plating, and the back end of the well plating is very often thickened up to guard against wear and tear caused by material dropping from the buckets as they pass over the top tumbler.

The Main Framing is a "trestle" consisting of two pairs of vertical legs (1) and one pair of sloping or "Spur" legs (2) formed of steel plates and angles and of box section with cross-ties; it is erected at the back of the well and extends down to the floor of the vessel.

The sloping or "Spur" legs (2) are fitted to the deck and supported by strong girders or webs under same, and are constructed and stepped at the top so as to support the cast brackets for the bucket ladder shaft (3), and from this centre the bucket ladder is radially lowered to dredge at various depths.

Immediately behind the bucket ladder shaft and fitted at the top of the vertical legs (1) are bearings to take the shaft (4) which carries the top tumbler with spur wheel on each end, and behind that again is fitted a shaft (5) with pinion wheel at each end meshing with the spur wheels, and driving same.

To control the spoil the Main Framing is covered in on three sides by steel plates, and at the deck level a door is fitted to give access to the bucket chain for inspection purposes.

At the top of the Main Framing where the bucket passes over the top tumbler, a steel mudguard is fitted, so as to guard the platform and gearing against any splashing of the spoil dropped from the buckets as they are inverted over the top tumbler.

Below the top tumbler and between the vertical legs (1) of the Main Framing a shoot (6) is formed to catch the spoil from the buckets, highest at the centre line of the vessel and inclined outwards to port and starboard sides. This shoot is composed of steel plates and angles. In the centre of the shoot and with its axis in a fore and aft direction, a hinged door or flap (7) is fitted which enables the spoil to be diverted to either side of vessel as desired; this door is composed of a heavy steel forging with thick plating on each side, the whole being of sufficient strength to withstand the severe shocks of large stones falling on it.

The shafting forming the hinge of this door is supported at the apex of the shoot by a saddle eye, and is so arranged that the shoot against which the door is resting is closed, thereby causing the dredging to be deposited on the opposite side. A heavy weight (8) is fitted to a lever on the door shaft and this arrangement enables the door to be hand worked by means of ropes and blocks (9) on deck.

Vertical legs (10) placed athwartship and supported by crossbeams carry the inboard part of the shoots. At the sides overboard hinged shoots are fitted to deliver the spoil to the hopper of the barge alongside. The shoots are raised or lowered as required by means of ropes (11) passing through pulleys (12) fixed to the end of the shoot and shoot standards, thereafter leading to hoisting barrels (13) fixed to framing legs; these barrels are connected by shafting and gearing operated by a separate engine (14) fixed to framing leg.

The Bucket Ladder is built of plates and angles and of box section and made strong enough to resist the many shocks and stresses acting on it, and its top end is suspended on the heavy shaft (3), which is supported by cast steel brackets fixed to the sloping legs (2) of Main Framing; the lower end of the ladder is specially strengthened, as here the bottom tumbler is supported in the heavy cast bracket bearings in which it revolves, between the two sides of the ladder.

On the outside of the ladder girders flat strips of plating or fenders (15) are fitted, which rub along similar strips (16) attached to the well side plating, with just sufficient clearance to permit the ladder to move easily up and down the well. On the upper side of the ladder are fitted the bearing castings which take the rollers (17) that guide the buckets (18) and chain or link (19) towards the top tumbler. Side slip is prevented by fitting a flange at opposite ends of alternate rollers.

The part of the ladder above deck is provided with mudguards on each side of the buckets, and the underside of the ladder is closed by curved plates to catch and convey any spilled spoil back to the well, so as to keep the deck clean. Near the lower end of the ladder a bridle (20) is riveted which takes a fixed shaft (21) carrying a number of single pulleys. A similar fixed shaft (22) with pulleys is fitted at the top of the Fore Framing (23), and a steel wire rope, the standing part of which is made fast to this shaft, passes successively round the lower and upper pulleys and so to the hoisting barrel (24). The correct

lead to the barrel is obtained by passing the wire over a "skewed" pulley (25) fitted on the top shaft (22). The hoisting barrel (24) is in the hold of the vessel, and is operated by gearing from a separate engine (26).

The length of the ladder depends on the dredging depth desired. When the enormous weight of a complete bucket ladder and chain, etc., is taken into consideration, it is apparent that the hoisting gear and frame work carrying same constitute a very important item.

The construction of the framework, called the "Fore Framing" (23) on which the hoisting gear is placed, is of a similar type to the Main Framing. Two vertical girders or "trestles" are fitted on each side, efficiently tied fore and aft by girders and cross tied athwartship. On the top of these fore and aft girders cast brackets are fitted to support the shaft (22) carrying the hoisting pulleys.

The transmission of motion to the bucket chain is obtained through a horizontal shaft (27) from Main Engine (28), fitted with bevelled gearing (29) to a vertical shaft (30), at the top end of which there is further bevelled gearing (31). This bevelled gearing drives a shaft (5) which carries a pinion at each end. These pinions engage with the main spur wheels mounted at each end of the tumbler shaft (4). The tumbler being four sided in section, each side takes a bucket or link in time. The velocity of the bucket travel is varied to meet conditions of material and depth through a clutch and gearing (32 and 33), independent of the main engine. A clutch (34) for disconnecting propeller is fitted at after end of main engine.

In order to avoid damage to the engine or gearing in the event of the buckets coming in contact with solid obstruction a "friction device" is provided on the outer rim of the main spur wheels by mounting the periphery part of the toothed gearing as a separate ring wound on a smooth central wheel and adjusted so as to give frictional grip for ordinary work, but "sliding" if solid obstruction is met.

The Fore Framing (23) is made high enough to permit the ladder and buckets to be lifted clear of the water when the vessel is steaming, thereby reducing the resistance.

The weight of the ladder and buckets is taken by one or more logs called "well logs" fixed to deck across mouth of well, the ladder is hove high enough to get the logs in position, and is then lowered on to the log and fixed to same by bolts or straps. Alternatively the ladder may be swung from the fore side of the Fore Framing by links engaging with eyes on the end of the ladder.

The Barge Loading Dredger requires more room to work in than the Hopper Dredger, but it has the advantage over the Hopper Dredger in that the dredging operations are continuous and no time is lost in lifting and laying moorings and in going to and from the dumping ground.

To control the dredger during the operation of dredging, outlying cables, anchors and winches are used. When working in free sand some difficulty is experienced in keeping the buckets full due to the agitation of the sand and the consequent loading of the buckets with a mixture of sand and water with sand in suspension. In sand and water, therefore, the buckets are run at a low speed, and in refractory material the bucket chain is speeded up to get the benefit of the impact.

The following particulars applicable to the above dredger may be of interest.

Two sets of buckets were supplied, one of 15 cubic feet capacity for use in hard material, and one of 28 cubic feet for use in soft material.

The travel of bucket in the former is 18 per minute and in the latter 12 per minute.

The total weight of ladder buckets and mountings complete was approximately 145 tons.

Hopper Barges.

The Bucket Dredger just described, being of the barge loading type having no hopper, is accompanied by a barge into which the dredged material is discharged.

These barges are of two types, viz.:—Hoppers with doors on the bottom and hoppers without doors on the bottom, and both may be either propelled or non-propelled and of ship shape or rectangular form. Those without doors are used where it is intended to rehandle the spoil for special reasons, and are emptied either by grab cranes or by special shore suction pipe arrangements. If the spoil has to be discharged into the open sea, sea-going Hopper Barges with doors are used, and are self propelled.

Outline Description of Hopper Barge. *See* Figs. 2 & 2a.

The Hopper (1) is open on its whole surface at the deck so as to permit of the spoil being distributed to the trim of the vessel, and the spaces (2) between the hopper sides and ship's side are usually arranged as buoyancy spaces. A coaming plate is fitted round the hopper at deck.

On the middle line and built on the keel, a box girder (3) is formed known as the Hopper Keelson.

The hopper bottom is sub-divided by low divisional bulkheads (4) spaced equally apart; trimming holes are made in these divisions for distributing the spoil. Between each divisional bulkhead a door (5) is fitted to permit of the disposal of the spoil. These doors are hinged at the bottom of the longitudinal bulkhead or hopper sides (6) on a fore and aft axis, and close against the hopper keelson. The hopper doors are made up of a steel plate ·40 in. thick, bound round by a 4 in. angle frame, and has three tail hinges (7) in its length riveted to plate and extending the full width of door. The tail hinges mate with knee-shaped hinges (8) riveted to lower end of hopper sides. The inside of the door is built up of 5 in. Canadian elm bolted through plate, with a 5 in. angle stiffener on top in way of each hinge and bolted thereto. A steel angle bar is fitted inside to take wood grounds on which the door closes. The outside surface of the door is kept one inch up from the base line.

The doors are raised and lowered by bridle chains (9) connected to suspension staples through door, which are set over at an angle to suit the lead of chain, these chains leading up to a heart-shaped plate (10) called a "Bridle plate," and from twin bridle plates (11) linked to same a single chain (12) is attached. This single chain is led over a pulley mounted on a Hopper Beam (13) to a hydraulic winch (14) on deck at each end of hopper. Each length of single chain controls two doors athwartship (one port and one starboard). All lengths of chain are fitted with stretching screws (15) for adjustment. The hopper beam consists of plates and angles and of box section, extending the full length of hopper at centre above the deck.

In the loading of hopper barges, the hopper doors although closed are not absolutely tight, as the sea-water leaks through so that the water level inside the hopper ordinarily is the same as outside the vessel. When the spoil and water is "shot" into the hopper the spoil setties on the bottom covering the doors and eventually sealing them, the dredged spoil continues to be "shot," the water gradually rising to the top and overflowing the hopper side coamings. When little or no water is left on the surface the barge is then considered to be loaded, the dredging operations are stopped, and the barge steams to the dumping ground. The doors in bottom are opened and the spoil discharged, after which the doors are closed and the barge steams back to the dredger for another load. If the spoil happens to be of a "clayey" nature some difficulty is experienced in dumping the barge. The clay becomes compacted in the pockets into a sticky mess arched across the door openings, and will remain so with the doors open. In such instances hydraulic jets are used for cutting up the spoil.

The hinging of doors vary and is decided by the requirements of the job. In the foregoing description the hinges are on the outer sides and the lifting gear and winches are in the middle line; as this arrangement may not always be suitable, alternatively the doors are hinged to the hopper keelson and closed on the outer sides, the chains being led up the hopper sides to deck level and thence to the winches. By this means the whole width of deck opening is clear. If cross ties are required, beams are fitted over the division plates at the deck level.

The sides of hull are usually protected by wood fenders at deck level and waterline to guard against damage that might be caused through vessel bumping against dredger whilst loading.

The weight of each hopper door in this instance is about 32 cwts.

Grab Dredgers.

The Grab Dredger is, in principle, a derrick crane mounted on a float or vessel of ship form and swinging a grab bucket. In fact, a crane and grab bucket could be fitted on board any vessel sufficient in size to contain same with some freeboard and with sufficient stability to keep the vessel in reasonable trim and to resist the listing moment of the swinging crane and bucket.

The breadth should be such as not to necessitate an excessive length of jib to reach, say, a barge loading alongside, and the freeboard sufficient to ensure some reserve bouyancy when the machine is at the point of maximum inclination due to the limiting position of the loaded bucket in its arc.

The type of bucket to be used depends on the quality of the material to be worked, and may be of the "Clam Shell" or "Orange Peel" pattern. The former has two jaws or shells, and the latter three or four, operated by wires or chains and sheaves for opening and closing.

The "Grab" is very useful in harbour and dock work and in salvage operations, as in working same it takes up very little space. It can also be used in the open sea in rough weather, having no fixed parts below the water. It is, however, best in mud or soft earth. The "orange peel" bucket is not so common as the "clam," but it is useful in picking up loose rock or other obstruction.

In operation the "clam shell" bucket is dropped to the river bed from the end of the derrick crane. The two halves of the bucket are then closed, and the hoisting machinery is set in motion to bring the bucket to the surface with its load. In the "orange peel" pattern the same method is adopted, the blades closing over the material to be raised in a somewhat similar manner to the fingers of a huge hand.

The "Grab" is very familiar, as it is used in harbours for loading many cargoes, such as coal, ore, sand or grain, and, under these circumstances, no special sketch of a grab dredger is shown. In fact, by fitting a grab crane and bucket on board the Hopper Barge, Fig. 2, you have a very common type of Grab Dredger.

Dipper Dredgers.

These craft usually consist of a non-propelling pontoon hull on which is mounted the dredging gear.

The Dipper Dredger digs like the familiar steam shovel, the bucket being a "scoop" with heavy teeth and a flap bottom. This bucket is attached to the end of a long handle called a "dipper arm," which is carried by a boom at or near the centre of the latter.

The boom is situated at the fore end of the hull and is set well forward in order that the dipper arm may be clear of the bow in all working positions, and is supported by a form of sheer legs or A. Frame stepped on the deck a little abaft the heel of the boom.

The dredger is held in position by three spuds, these spuds being long steel girders of heavy section with pointed shoes, and are suspended from gallows frame and run vertically through recesses in ship's hull. They are raised by hoisting engines, and when released penetrate into the river bed by virtue of their own weight, thus anchoring the hull and holding it in position while digging.

The bucket obtains its load by digging into the bottom under the impetus of the dipper arm and bucket wire, which runs over a sheave in the boom head and thence to the main engine.

The boom is fixed to a revolving table and swung by means of same, operated by the necessary wires and pulleys and controlled by a swing engine.

Outline Description of Dipper Dredger. *See* Figs. 3 & 3a.

The hull to carry the working gear forward is rectangular in form and of box section and non-propelling, and is of sufficient dimensions to contain with comfortable freeboard all the gear necessary, including machinery, boilers, etc. The beam and length forward and aft of the A. Frame (1) is sufficient to provide adequate stability when dredging to keep the ship in reasonable trim and resistance to the listing moments of the swinging boom (2) and bucket (3). The bow structure and support in way of boom, etc., is of great stiffness to withstand the stresses of the dipper at work and the extreme forward mounting of the boom.

The bucket (3) is an open steel cylinder provided with a hinged flap bottom (4), a handle or bail (5), and a reinforced cutting edge or lip (6) to which teeth are attached. The capacity of the bucket is 6 cubic yards.

The bucket hoisting wire (7) is made fast to the centre of the bail (5), and the backing wire (8), which draws the bucket (3) and dipper arm (9) back towards the hull, is fastened to the dipper arm near the bucket. The bottom door or floor (4) of the bucket is held closed by latch gear (10), composed of bar and spring, which locks automatically by virtue of its bevelled end. The latch gear is drawn back to open by means of a wire (11) operated from the heel of the boom.

On the deck at the fore end of hull is fixed an annular casting (12) mating with a similar casting (13) which is free to rotate, and on this casting the revolving table (14) rests, and is free to oscillate slightly.

The revolving table is formed of plates and angles. The boom (2) is fixed to the revolving table (14) and is of heavy make, formed of plates and angles and of lattice construction, its upper end is hung from the peak of the A. Frame (1) by a topping fall (15) of fixed length, so that the boom has a constant inclination of about 45°.

The A. Frame legs (1), which are also of lattice construction, are fitted into sockets on deck just abaft the heel of the boom and are tilted forward with the top centre above the centre of the revolving table. The back guy ropes (16), from the top of sheer legs to aft end of hull, hold the A. Frame legs in position.

Round the edge of the revolving table (14) a groove is fitted which takes wires led from the swing engine (17) for swinging the boom. This is done by means of two wires led from the barrel of swing engine (17) through two horizontal pulleys fixed to deck, one wire leading through pulley on starboard side and the other through pulley on port side, thence round groove in revolving table to a fixed point about the centre at fore end of table.

The dipper arm (9) is of strong section and made of wood bound by steel plates bolted to same. A "Slot" is formed in the centre of arm and extends through the arm for about 50 per cent. of its length from the top or inner end. A rack is fixed to under side of dipper arm on each side of "Slot." The dipper arm is held to the boom by means of a saddle (18) extending through the "Slot" in the arm from the under to the top side and to a guide plate which bears against the upper side of arm. The saddle (18) is "sleeved" to a shaft (19) which carries a large spur wheel (20) on one end and brake wheel (21) on the other end, also two small pinion wheels (22) on each side of centre. The large spur wheel (20) meshes with a sliding pinion wheel on crank shaft of boom engine (23) which is bolted to the boom, and the small pinions (22) mesh with the rack on the under side of dipper arm. The brake wheel (21) has a steel friction band fitted round its rim, and is operated by means of a steam brake cylinder (24) fixed to lower side of boom.

The dipper arm has two movements, one of translation with respect to and through the boom at or near its mid point, and the other of rotation in a vertical plane through an arc centred at the same point. The motion of the dipper arm through the boom is controlled by means of the boom engine (23) transmitted through connecting rods to crank shaft and sliding pinion, which meshes with large spur wheel (20) on shaft (19) driving the pinions (22) which mesh with the rack on dipper arm, so that the arm may be "pushed" or "pulled" through the boom or held at any point of its length by the application of the brake. By this means the dipper arm can be thrust out beyond the end of the boom to an increased outreach. The movement of rotation on the saddle (18) is effected by means of the hoisting wire (7) or the backing wire (8).

There are three spuds let into recesses in hull of vessel, two forward (25) and one aft (26) on centre line at stern, sufficient clearance being made to permit of perfect freedom of operation. The spuds are steel box girders with pointed metal shoes at end. The two forward spuds (25) are suspended from tall vertical rectangular frames called Gallows Frame (27) (which are formed of plates and angles lattice construction), they are controlled by spud hoist engines (28) with the necessary pulleys and wires. The aft spud is controlled by a small winch (29) and pulleys and wire connected near its lower end, and is held in position by a saddle (30).

In the operation of lifting the spuds, a hoisting wire from barrel of spud hoisting engine (28) on either side in the hold passes round a bevelled pulley (31), thence up through the deck to pulley (32) at the top of gantry, down round double pulley (33) on top of spud, and up again to gantry attachment (34).

To "pin up" is a term applied to the process of maintaining the dredger upon an even keel while digging by transferring part of the weight of the dredger to the two bow spuds, so that it is not dependent upon the stability of the hull to resist transverse oscillation. This is done by means of a wire led from barrel of spud hoisting machine (28) in hold, passing round bevelled pulley (35), thence through deck to pulley (36) on inside of spud framing, up round double pulley (33) on top of spud and down to turnbuckle (37) on outside of spud framing.

In operating the dredger, the bucket hoisting wire (7) is slackened, the dipper arm friction brake released, and at the same time the dipper arm is pulled back towards the hull by stressing on the backing wire (8), the arm coming down through the boom until the bucket rests on the ground. The backing

wire is then released, the friction brake applied, thus fixing the radius of the dipper arm, and by stressing on the hoisting wire (7) the bucket cuts its way forward in an arc of radius equal to that portion of the dipper arm below the boom, until it is loaded and clear of the mud, whereupon on releasing the brake the arm comes up through the boom. The bucket having obtained its load, the revolving table (13) is rotated until the bucket is over the hopper of the accompanying barge, the latch gear (10) is then pulled and the contents of the bucket dumped.

The dredger may advance by grounding her bucket well ahead of the bow, raising the two forward spuds (25) clear of the bottom and stressing the backing wire (8), which pulls the hull towards the dipper arm. The stern spud remains in the mud during this operation and having a "slotted" well slowly inclines forward as the dredger progresses. It is on this account called the "walking spud." This inclined position of the after spud forms a backing resistance to the thrust of the dredging bucket when in action.

The dipper dredger is well adapted to hard digging and to the removal of material containing a large amount of obstruction, It can handle stones, boulders, and wreckage of almost any kind.

The following particulars applicable to the above dredger may be of interest :—

Weight of Boom	approximately	50 tons
,, Dipper Arm	,,	16 ,,
,, Bucket	,,	10 ,,
,, Spud	,,	9 ,,

This dipper dredger digs 255 cubic yards per hour, at a radius of 90 feet and a clear height of 30 feet.

Suction Dredgers.

There are two classes of suction dredgers in general use, the "River" type and the "Sea-going hopper" type, but the principle is the same in both types.

The "River" type hull is usually of rectangular or pontoon form and non-propelling, and is intended to be used in calm waters of rivers and sheltered harbours, and are radially fed with spud anchorage, or anchors and wires, or a combination of both. Briefly, the suction dredger consists of a centrifugal pump driven by a steam engine or motor carried in a hull and equipped with a hinged ladder carrying both suction pipe and cutter head, and having some means of position control and feeding movement.

The three principal functions of these dredgers are, first, the breaking up or cutting of the bottom material so that it readily may be drawn into the suction pipe; second, the horizontal and vertical movement of the suction pipe and cutter so that the material may be fed constantly to the suction; third, that of pumping the material through suction pipe, pump and discharge pipe into a spoil basin or the adjacent deep water.

The first is accomplished by means of a rotating cutter at the suction end of the ladder, keyed to a shaft carried on the ladder and driven by an engine called the "cutter engine" located at the ladder hinge. The cutter "slices" up the ground so that the spoil may be readily drawn up by the suction. The vertical movement of the second function is obtained by a boom ("A" frame if fitted), back guys, falls and hoisting engine, by which the ladder is raised and lowered. The horizontal movement, laterally, is effected in one of two ways; either by swinging the dredger and ladder as a whole about one of the two stern spuds as a pivot, or by swinging the ladder only, the dredger being held stationary by three or four spuds. The forward movement or the "advance in cut" is obtained in the first instance by the alternate use of the two stern spuds, and in the second by "walking" spuds. The third function is accomplished by the pump and its drive with the accompanying suction pipe, floating discharge pipe or pontoon line, and the shore pipe line.

The size of the pump varies according to the work to be done and the material to be lifted, and is designed to take anything that can pass through the cutter head and into the suction. The cutter heads are of various types, and are used subject to the character of material being lifted and the judgment of the dredging men in charge. To exclude stones and other obstructions various straining devices are used, either in the cutter itself or attached to same.

The hinged ladder which carries the suction pipe may be a steel box girder enclosing the pipe, or a pair of plate girders braced together or a pair of lattice trusses, and is set in a "well" or "recess" in the

centre at the bow of the dredger. The ladder is suspended from a boom head by a wire fall, which is purchase rigged to the ladder near the cutter head and partly bridled to relieve the bending stresses on the ladder. The boom is set well forward at a fixed angle of from 30° to 45° from the horizontal, and the "A" frame (if fitted) is usually vertical. The maximum depth below the water surface to which a dredger can dig is determined by the length of ladder and the hinge construction.

The arrangement of spuds depends upon the method of feeding. The swinging dredger has two spuds set in the same transverse plane at or near the stern of the dredger. When working, one spud is always up clear of the bottom and the other down in the mud, forming the pivot about which the dredger rotates or swings. This radial motion is effected by two swinging wires extending from two anchors, one on each side of the bow, to the winding drums on the dredger. When it becomes necessary to advance the dredger in order again to thrust the cutter into the bank, this movement is accomplished by dropping the high spud and raising the other when the dredger has swung to the limit of the cut. Thus the new pivot is further ahead in the cut, and the centre of rotation therefore advanced. In this manner the dredger moves ahead by the alternate use of the two spuds.

The swinging ladder dredger has four spuds, two forward and two aft, all of which are in the mud while pumping. Thus the hull is held, while the ladder is swung by means of swinging wires from cutter head to winding drums after passing through guide sheaves at the bow corners. At least three of the four spuds are set in slotted wells, permitting them to incline forward from the vertical, and are called "walking spuds." Two wires extend from the two forward spuds, at or near their toes, to sheaves on the stern corners of the hull, thence to drums of the winding engine. To move ahead these wires are wound on the drums, pulling the dredger forward and inclining the spuds. When desirable the walking spuds can be raised and plumbed, one at a time. The swinging ladder dredger makes a much narrower cut than the swinging dredger, and can, therefore, work in a more confined space, and the absence of side wires is often an advantage, as they interfere with traffic in the vicinity of the dredger.

In many cases vessels having spud and spud handling appliances are fully equipped with all the necessary machinery and appliances for operation by wires and anchors, and although the spud method is more convenient through the saving of time in removing wires and anchors and through non-interference with traffic and adjacent structure, yet there are times when wires must be used, as in deep water or in swift currents, or in the event of the breaking of a spud. I have mentioned the spud anchorage because these spuds being less familiar no doubt to you all than the "Arran Chief" variety, it might be of interest.

The total length of discharge pipe line comprises three distinct parts:—First, the portion on the dredger from the pump to the point of leaving the hull; second, the floating or pontoon line; and third, the shore line. Since the first constitutes a permanent integral part of the dredger, and also because any break therein might flood the hull, it is made of heavy cast iron pipe with flanged joints.

The discharge pipe from pump may be a direct lead to side of hull or through the inside of hull to stern, or it may lead up through the deck at pump and extend aft on deck over stern, where it is connected by ball-joint to another pipe which is connected in turn to the floating pipe line.

The floating line from the hull to the shore pipe consists of a series of pontoons, each carrying a section of pipe so coupled together as to provide the necessary flexibility to allow the dredger to swing and advance, or in other words to "wag her tail." These pipes are built in as long lengths as practicable and are coupled together by ball-joint connections. The shore pipe is built in sections, of such a length that the weight is not too great for man-handling, and each section is connected by a slip-joint.

In general appearance, the above type of dredger resembles the "dipper," shown in Fig. (3), minus the dipper arm.

In sea-going dredgers the dredging pipe can be fitted in various ways:—

(1) Dredging pipe in a well (same principle as the bucket ladder).

(2) Dredging pipe connected to side of hull, pipe always overboard, or capable of being taken inboard when not in use.

(3) Dredging pipe connected to deck and taken inboard when out of use.

OUTLINE DESCRIPTION OF MODERN SEA-GOING SUCTION DREDGER. *See* FIG. 4.

This vessel is a Twin-Screw Stern-Well Hopper Dredger of ship form, containing pumping plant with hopper for receiving and transporting the material, and in addition is equipped with all the machinery and appliances necessary for navigation. As the "well" is fitted aft it permits the bow of the vessel being as perfect as the ordinary sea-going vessel, as well as improving the vessel's steaming qualities. It has two sternposts and two rudders. The boilers being forward and the engines aft of the hopper, the steam pipes are led through the buoyancy spaces at ship's side.

The vessel has twin sets of engines (two port and two starboard), driving propellers on the after side and pumps on the forward side. Three clutches are fitted on each line of shafting, one between propeller and after set of engines, one between forward and after sets of engines, and one between pump and forward set of engines; so that either or both sets of engines can be connected to propeller or pump as desired. This vessel has a "Twin" suction pipe in the aft well and another suction pipe for emptying hopper, led through hopper keelson and connecting with deck and shell discharges. Two pumps are fitted to operate the above. The "Twin" suction pipe operates in the central aft well and is carried inside ladder hinged at top of well, it is raised and lowered by blocks and tackle operated by a hoisting engine on deck. The suction pipe has ball-joint connections in way of ladder hinge to accommodate itself to the various dredging depths, "rubbers" being fitted to sides of ladder and bearing on well sides to provide athwartship support. The suction end which rests on the ground is provided with a "clot" or scraper to feed the pumps when "trailing."

The vessel is capable of discharging her spoil either:

(1) Through a pipe (A) into self-contained hopper.

(2) Through pipe (B) in vessel's side plating (linked up with pontoon pipe line ashore) should the spoil require to be delivered some distance from vessel.

(3) Through pipe (C) rising above deck and operated by crane, discharging into a barge alongside or linked to a pipe line supported by trestles to a short distance ashore.

(4) Through doors (D) in bottom of hopper.

The inside of the hopper up to the height of the hopper keelson is constructed in the form of "bins" with sloping ends, so that the spoil falls readily towards the hopper doors through bottom of vessel.

If the hopper has been filled and it is desired to transport the spoil and discharge same some distance from the dredging site, this is arranged for by having a suction pipe within the hopper keelson connecting with the deck and shell discharges. Sluices (E) in the hopper keelson sides enables the spoil to be pumped from the hopper through the line (F) at pump room bulkhead.

Owing to the tendency of the spoil to consolidate at the bottom of the hopper during transportation, hydraulic jets called "Water Jet Agitators" (G) are fitted to "stir up" the spoil, so that the material may more readily be sucked up by the pumps.

In the operation of dredging, the vessel steams to the dredging area, and before commencing "Trailing" the speed is reduced, the suction pipe with clot is lowered until it rests on the ground, and the vessel then moves continuously at a low speed over the area scraping and sucking up the sand and discharging same into the self-contained hopper. The large amount of accompanying water pumped up with the spoil is partly drained off over the raised coamings at hopper sides.

The above operation is performed by steaming with the two after engines and pumping with the two forward engines, the shafting between aft and forward engines having been disconnected by clutch. When the hopper is full the suction pipe is raised and the vessel steams to the dumping ground, where she discharges her spoil through the hopper doors (D) in bottom, the doors being operated by chains and winches as in the hopper barge (Fig. 2). One advantage of this method of dredging is that no anchorage is required (as has to be done in the bucket dredger), and there is no obstruction to navigation. A disadvantage, however, is the discontinuity of dredging operations and the loss of time due to the frequent trips to the dumping ground, and also that a certain weight of water has to be carried with the spoil.

In dredging while the vessel is stationary and at anchor the propeller shafts are disconnected by clutch, and two or four engines used, as desired, for pumping. In the above operations the "clot" is

replaced by a "cutter head." The spoil can be discharged by any of the methods previously stated. To prevent damage to pumps gratings are fitted to mouth of suction pipe, thus limiting the size of heavy solids passing through same.

The output of all suction pump dredgers depends largely on the quality of the material to be dredged, and one method of testing the dredging capacity, i.e., of solids lifted, is by pumping the discharge into a large empty tank of known size for a certain number of hours (the tank being large enough to avoid an overflow) and thereafter allowing the solids to settle. When this has taken place the total volume of water and spoil is measured. The water is then drained off and the amount of spoil remaining measured. From such data it is possible to state exactly the dredging capacity. If the discharged dredgings go into a comparatively small tank it will speedily become filled and overflow, and the loss of solids with such overflow is considerable and is further augmented by the commotion caused by the discharge agitating the solids already settled. This loss by overflow and commotion while discharging into a barge or self-contained hopper is the most serious deficiency of suction dredging, but is quite absent in cases where the discharges go into a space devoted to reclamation.

The suction dredger is, however, a particularly efficient instrument in that it not only dredges the material but can also deliver it to the place and at the elevation desired in one operation. While it can be used in all classes of material short of solid rock, it is most efficient in handling homogeneous material that is not necessarily hard such as silt, mud, sand, clay and gravel free from obstruction. Mud and fine sand, however, are regarded as the best hydraulic materials. The pump can handle a great percentage of solids when working in clay, but difficulty is experienced in agitating and cutting it in sufficient quantity to maintain the feed at the maximum capacity, hence the use of the cutter head at mouth of suction pipe.

The capacity of the hopper in this vessel is 16,200 cubic feet and can be filled in one hour while dredging at 40 feet depth below water-line.

The foregoing covers the types of dredging craft commonly in use. The choice of plant best adapted to a particular piece of work, whether the decision is the responsibility of the engineers or the contractors, should be given due consideration by men of ripe experience. Some of the factors governing this selection are :—

(1) Nature of spoil.

(2) Proximity of free dump.

(3) Kind of plant available and the relative efficiency of units of same type.

(4) Space limitations and interference with continuous traffic.

(5) Depth limitations so that the dredger may float.

(6) Time limitations.

The question of structural strength in these craft does not arise to any very serious extent in view of their size and proportions, and of the scantlings of which they must be constructed in order satisfactorily to withstand the wear and tear conditions encountered. With regard to the local stiffening in way of such parts as main, fore and after framing in bucket ladder dredgers or cranes, booms, derricks, etc., in other types, efficient and effective arrangements can generally be made, as in these craft no obstruction or limitations, such as are found in passenger and cargo vessels, are encountered.

In conclusion, I should like to acknowledge my indebtedness to those members of firms who supplied information and use of diagrams, and to thank them for their willing assistance. It will be realised that these craft described are to a great extent simply tools, the hulls being in many, though not all cases, simply floating structures for carrying the gear and housing the machinery. Thus their construction and operation involves a number of mechanical engineering considerations which I would not have attempted to include, even if I were able, and which, thank heaven, I am not. At the same time, if the paper has made clear to some the main considerations obtaining, and the methods adopted for dealing with them, the author will be well satisfied.

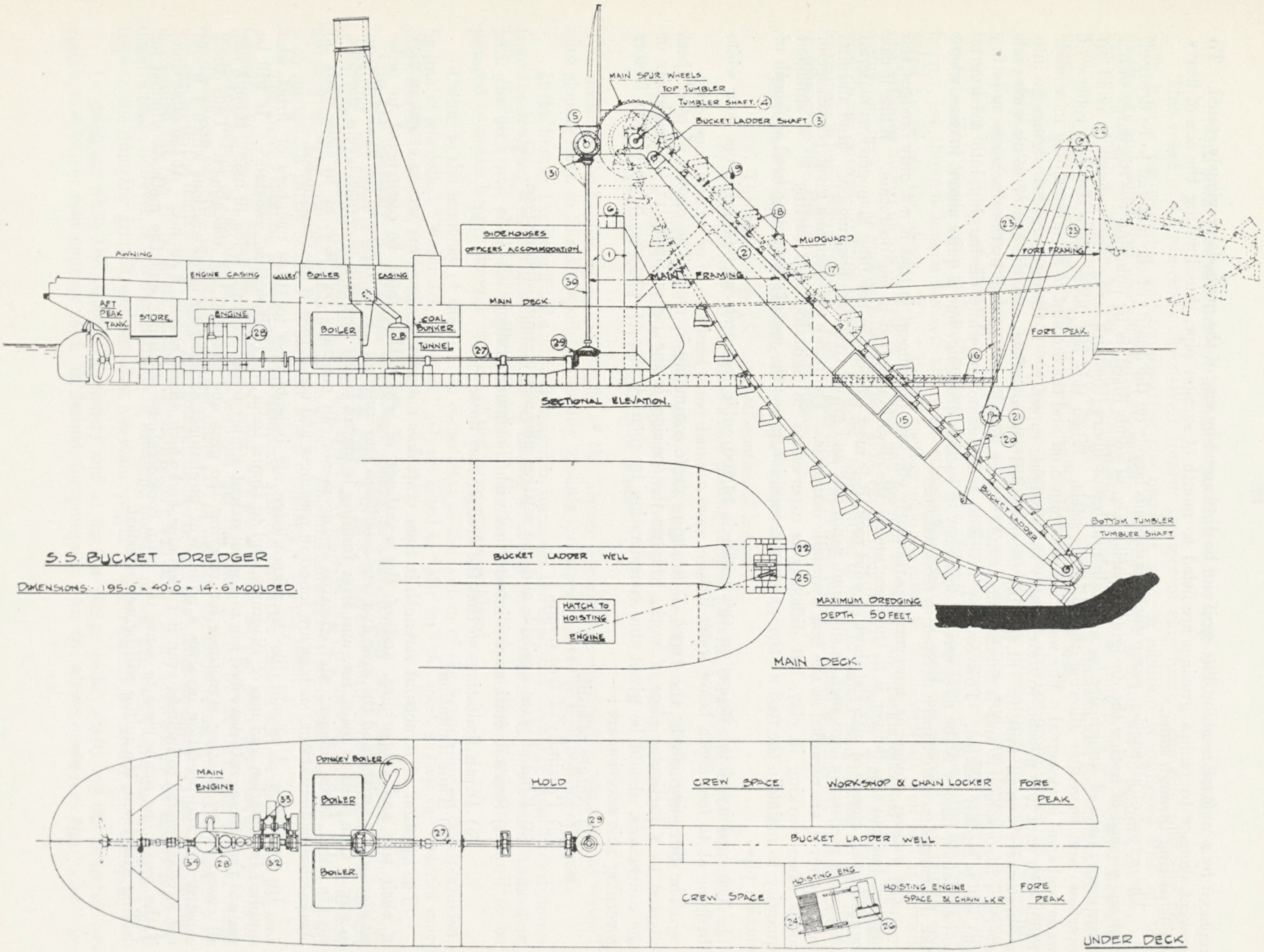

MAIN SPUR WHEELS
TOP TUMBLER
TUMBLER SHAFT
BUCKET LADDER SHAFT
MUDGUARD
MAIN FRAMING
FORE FRAMING
SIDE HOUSES
OFFICERS ACCOMMODATION
AWNING
ENGINE CASING
GALLEY
BOILER
CASING
AFT PEAK TANK
STORE
ENGINE
BOILER
D.B.
COAL BUNKER
TUNNEL
MAIN DECK
FORE PEAK
SECTIONAL ELEVATION.
BUCKET LADDER
BOTTOM TUMBLER
TUMBLER SHAFT
S.S. BUCKET DREDGER
DIMENSIONS: 195-0 x 40-0 x 14-6 MOULDED.
BUCKET LADDER WELL
HATCH TO HOISTING ENGINE
MAXIMUM DREDGING DEPTH 50 FEET
MAIN DECK.
MAIN ENGINE
DONKEY BOILER
BOILER
BOILER
HOLD
CREW SPACE
WORK-SHOP & CHAIN LOCKER
FORE PEAK
BUCKET LADDER WELL
CREW SPACE
HOISTING ENG.
HOISTING ENGINE SPACE & CHAIN LKR
FORE PEAK
UNDER DECK

Figure 1.

FIGURE 1A

BUCKET DREDGER

SECTION IN WAY OF SHOOTS

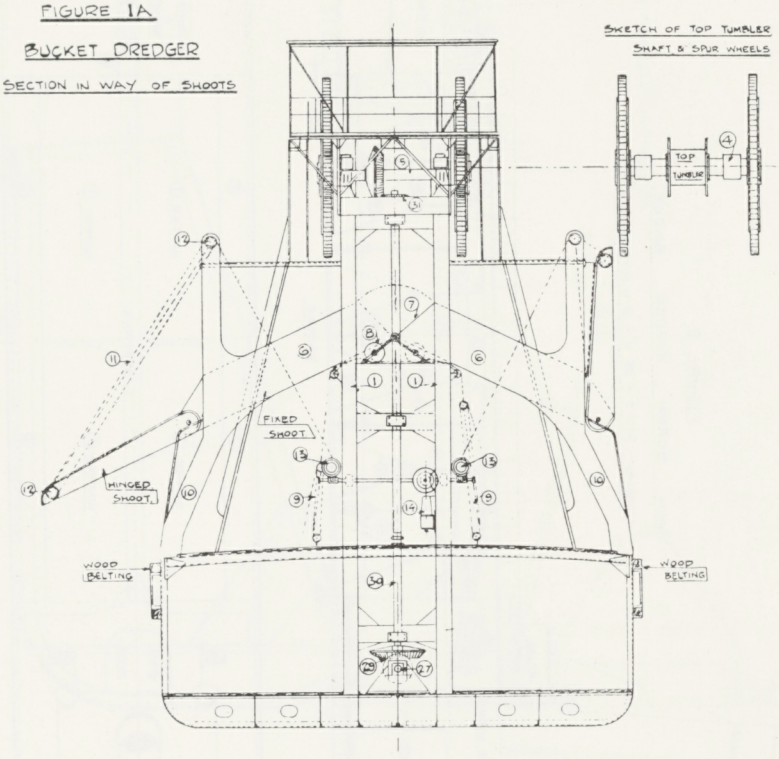
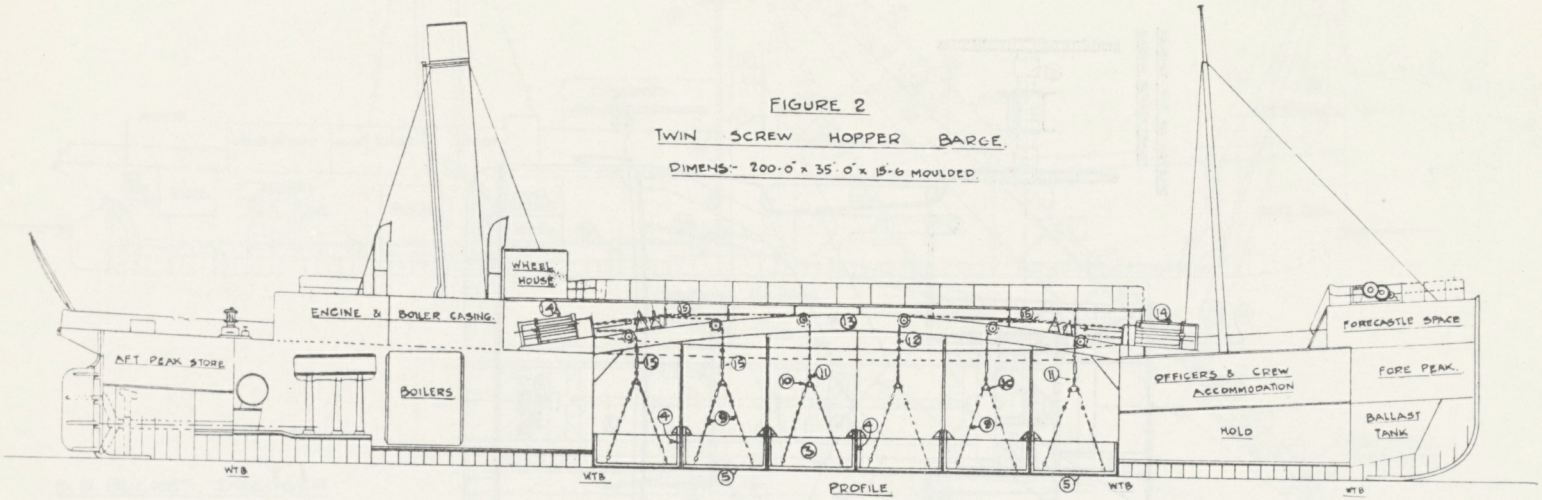


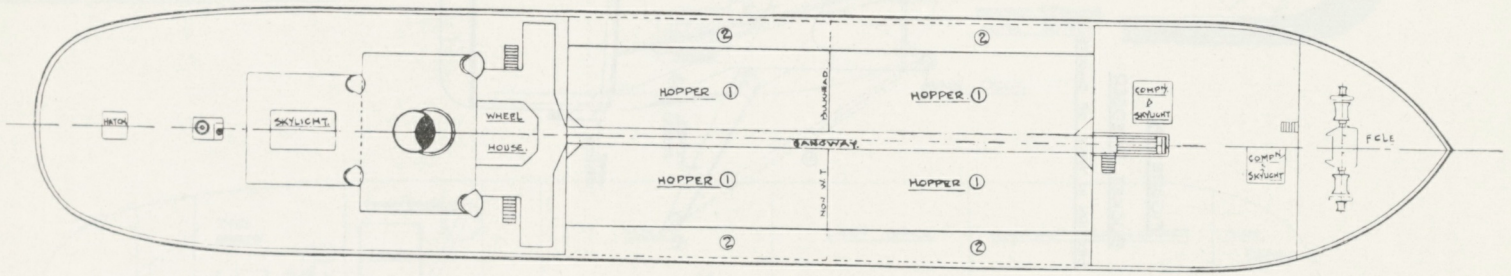
FIGURE 2

TWIN SCREW HOPPER BARGE.

DIMENS:- 200·0" x 35·0" x 15·6 MOULDED.



PROFILE



DECK PLAN

FIGURE 2A

TWIN SCREW HOPPER BARGE

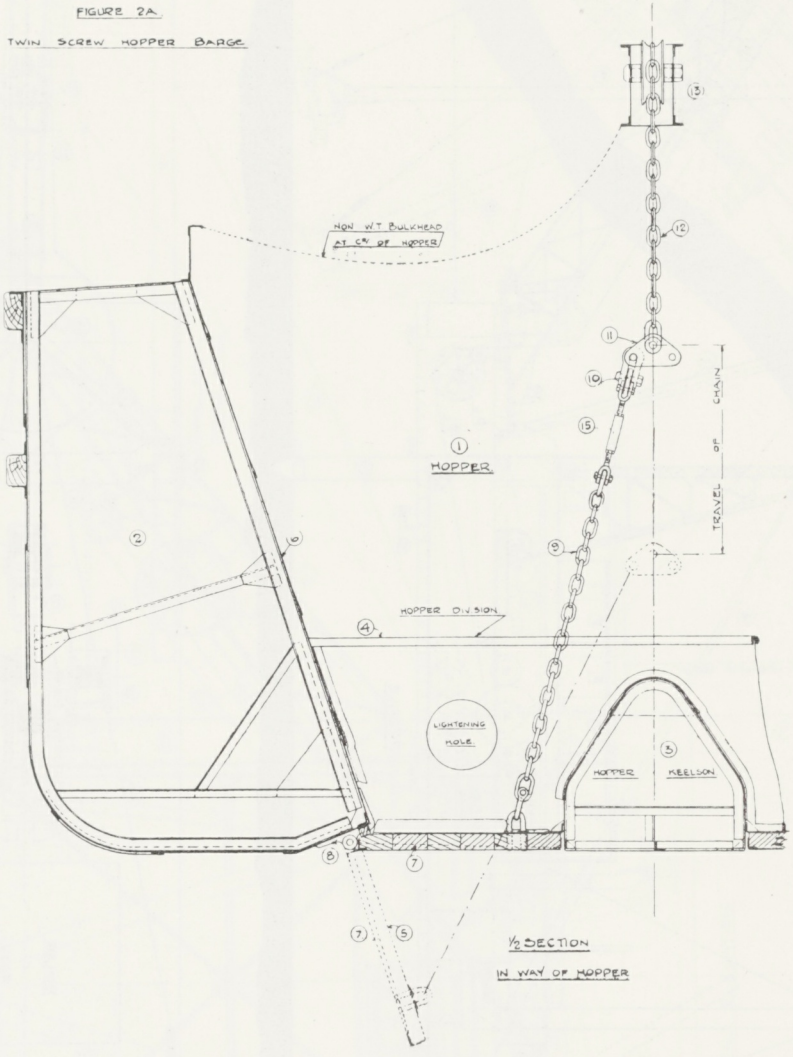
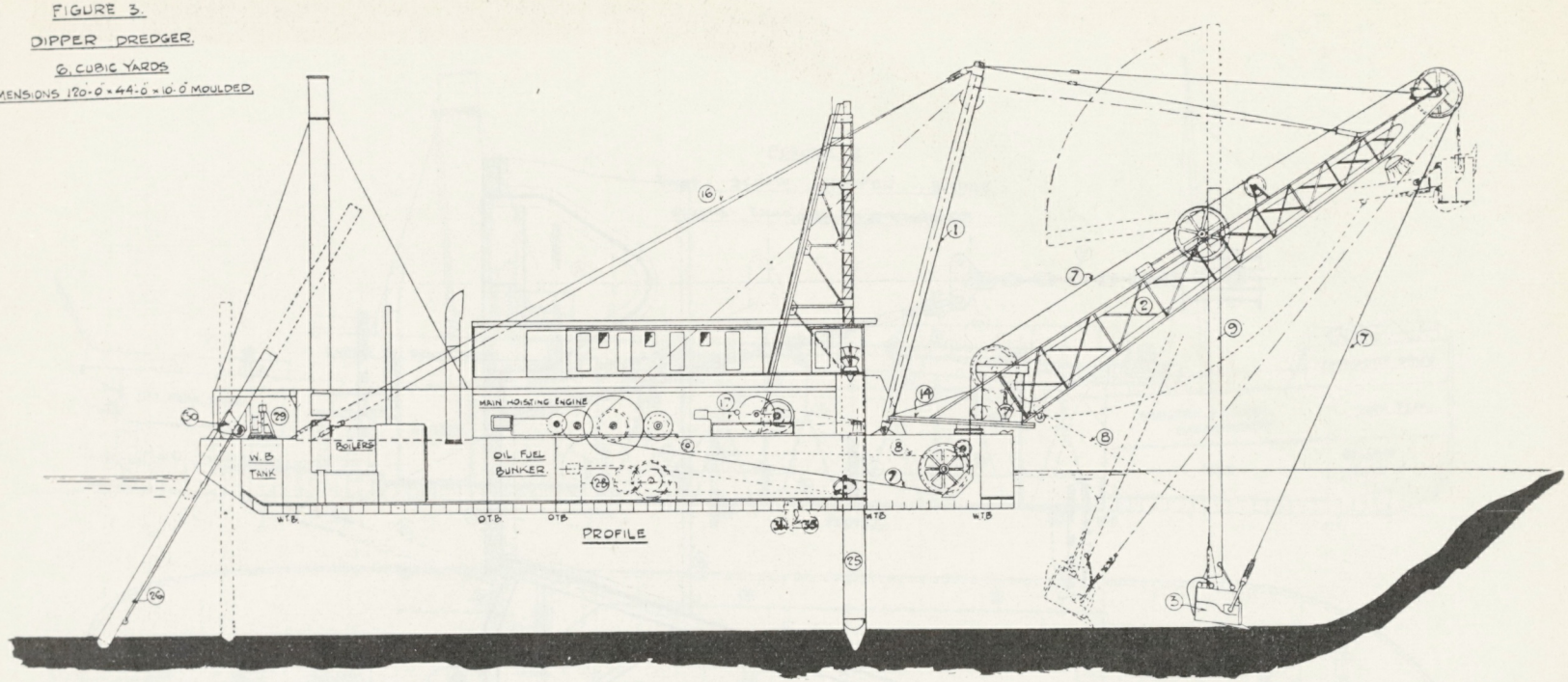


FIGURE 3.

DIPPER DREDGER.

6 CUBIC YARDS

DIMENSIONS 120'-0" × 44'-6" × 10'-0" MOULDED.



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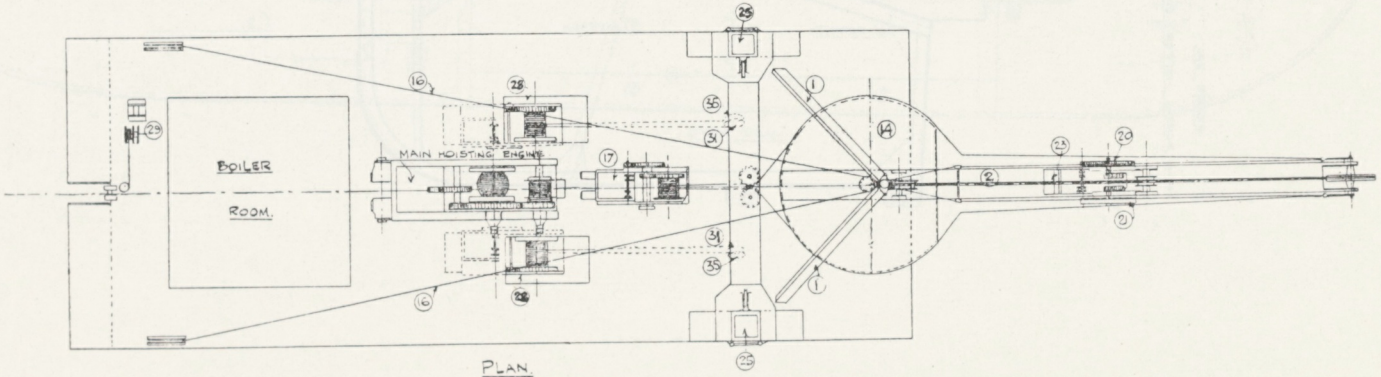
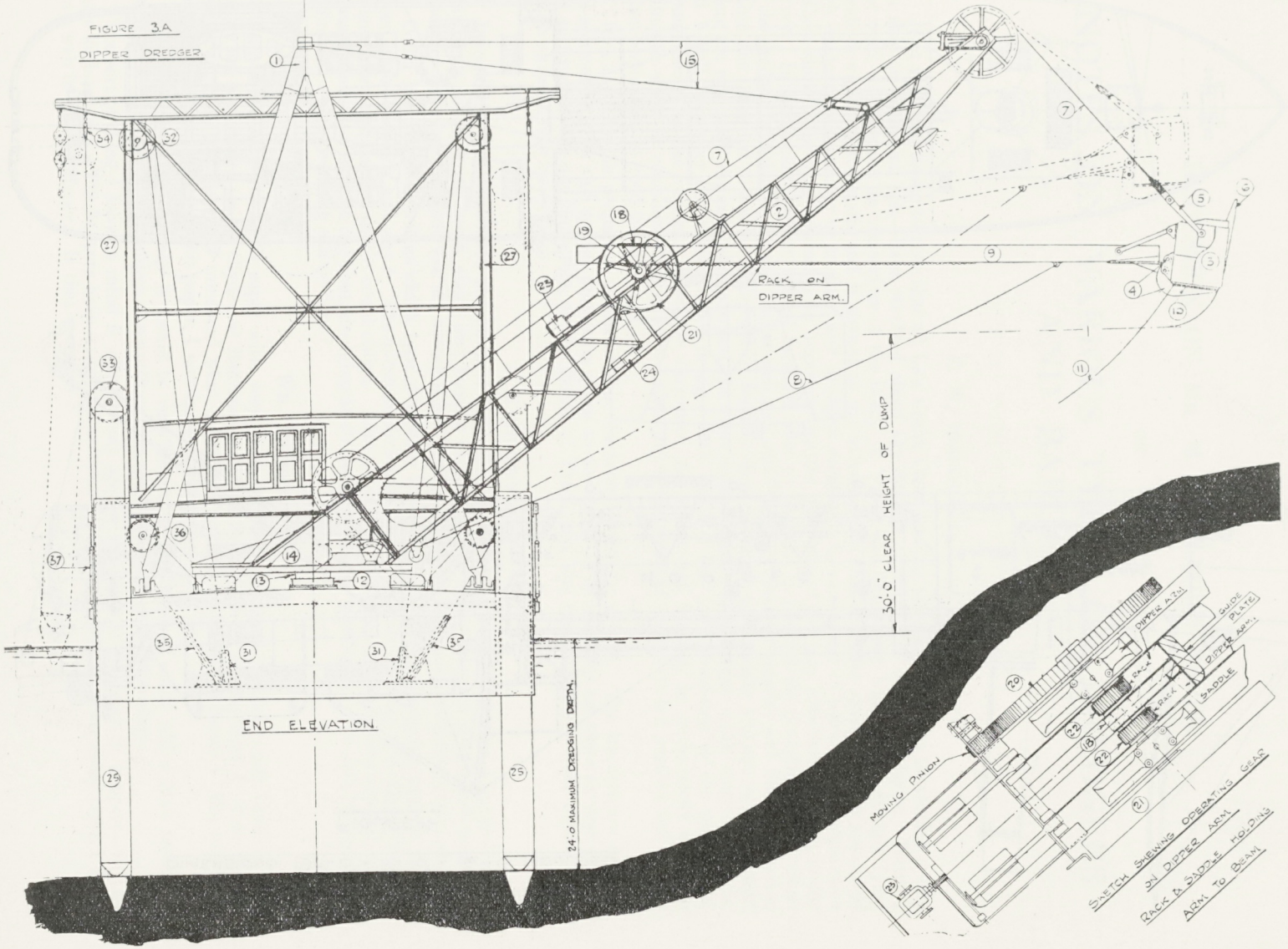


PLAN

FIGURE 3A

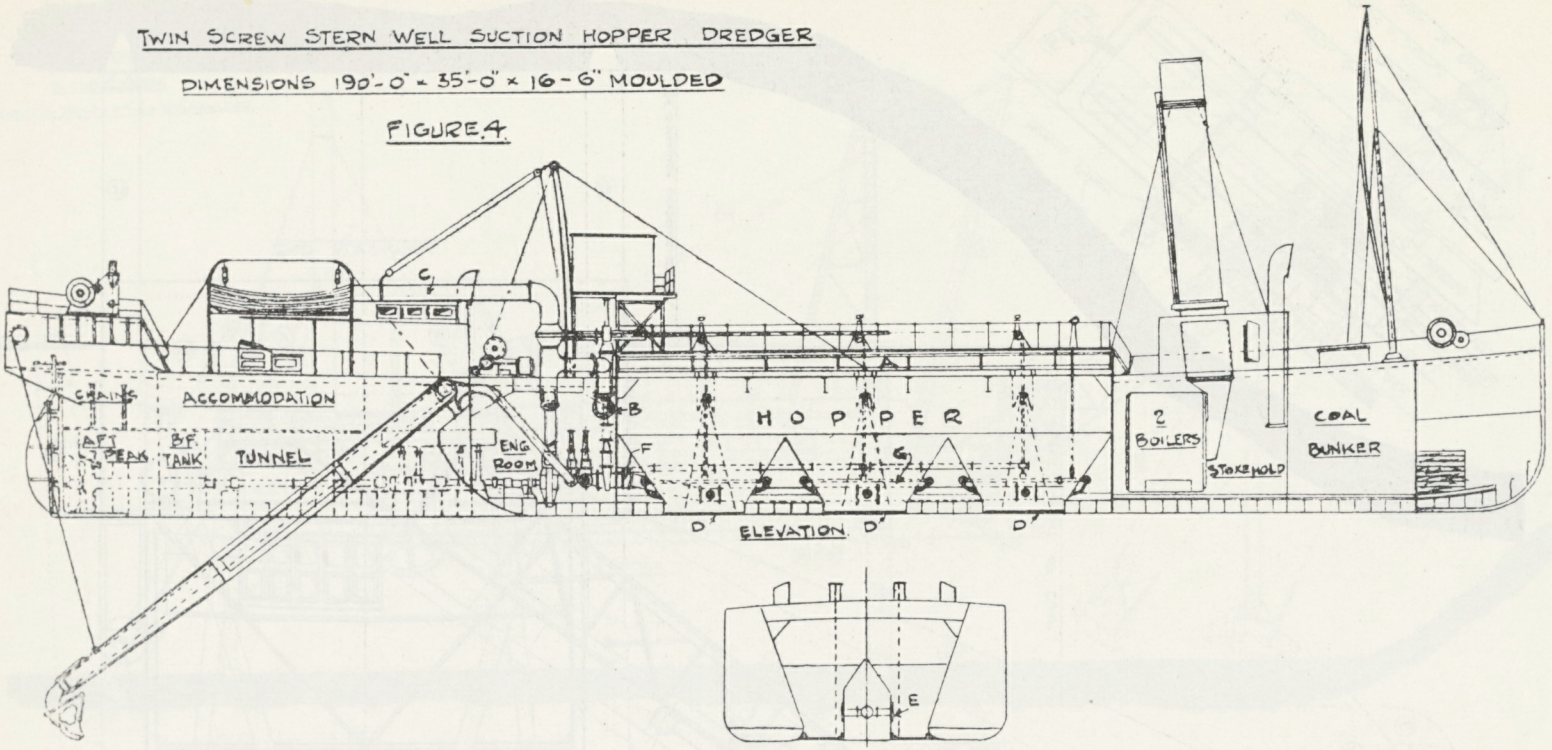
DIPPER DREDGER



TWIN SCREW STERN WELL SUCTION HOPPER DREDGER

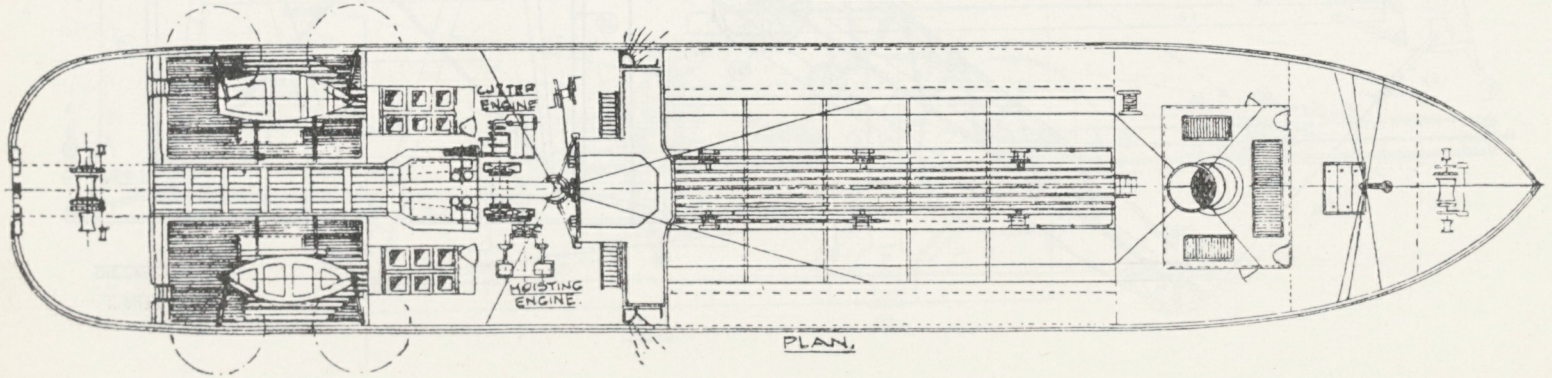
DIMENSIONS 190'-0" × 35'-0" × 16-6" MOULDED

FIGURE 4.



ELEVATION

SECTION THRO' HOPPER



PLAN.

DISCUSSION ON Mr. M. MACLEOD'S PAPER

ON

NOTES ON VARIOUS TYPES OF DREDGERS AND BARGES.

E. W. Blocksidge.

It is very interesting to note that all Law Court Cases relating to small ships—as to whether a ship is a ship or something else—have revolved about the dredger or small type of hopper barge. When I first went to Greenock in the service of the Board of Trade, the first thing I saw was a dredger lying upside down in the Gareloch, and it seemed to me, subsequently, that I always appeared to be associated with dredgers in some way or another, and dredgers eventually became a sort of scare. The preparation of these ships for a voyage abroad is an important matter, and some of you may have been engaged in the survey. In the bucket dredger, special facilities have to be fitted to prevent the pounding of the waves on the dredger by boarding up the bucket-well and caulking it as far as is possible and fitting a suction within the space led to a small pump above, because there is bound to be slight leakage on the voyage. There are not many skippers who have had the experience of handling a dredger under these conditions, and I well remember one taking out a dredger with which I had been associated in the preparation arrangements for the voyage. When he discovered the bucket-well leaking, he immediately made for Falmouth where he remained until relieved; after which the vessel proceeded on her journey and arrived at her destination in good condition.

It is a tricky job preparing vessels of this character for a long voyage. The buckets are lowered and secured on deck and special protection given to the crew. The occasions for these surveys are not now so frequent for our Surveyors, as the Board of Trade take the responsibility for the oversight of British ships in this respect.

J. G. Buchanan.

I would like to congratulate Mr. Macleod for giving us some good information on a subject which many of us do not know much about and because of that reason, there does not seem much scope for criticism; however, if I could ask the author a few questions, further information might be gained.

Could Mr. MacLeod tell us which type of dredger is used for the deepest dredging, whether ladder, dipper, grab or suction and why? The question obviously comes under the heading of dredging and not dredgers, but perhaps the author could oblige. Also on page 11 he states that a suction dredger can do a certain amount of work in one hour, dredging at 40 foot depth below water-line. Can this be considered the limit at which dredging can be done?

Wm. Thomson.

I am sure I have read this paper with very great interest. As most of these craft built in this country are constructed on the Clyde—at Renfrew—and as I lived there for a long time, I often viewed these strange contraptions and wondered what were their various purposes. Thanks to the excellent diagrams and descriptions in this paper, I now have a pretty good idea.

It has occurred to me that it would be very helpful if Mr. Macleod could add a little technical information in regard to the subject of scantlings that might be adopted in these ships.

The sort of thing I have in mind is whether any special thickness is required in hoppers—in the centre keelsons, etc. The hoppers have struck me as being excessively stiffened. In many cases I have seen a web in every stiffener. Is that necessary?

Could he tell us how these vessels suffer deterioration in view of their special service, as compared with a cargo ship? Is there greater wear and tear in dredgers, etc., and if so, what precautions are taken.

That is the sort of thing I have in mind, and it would add appreciably to the value of the paper, if Mr. Macleod could give some information of this kind.

C. Lloyd Roberts.

While the general arrangements of the type of craft described in Mr. Macleod's paper may be fairly familiar to those of his colleagues whose duties bring them to their notice, there must be a considerable number of the younger members of the Staff to whom this paper will be most useful, in that they may never have previously professionally considered such vessels.

A point was raised during the discussion following the reading of the paper in regard to the nature and extent of wear and tear repairs which might be expected when the hoppers or dredgers were undergoing their periodical surveys. While a fair proportion of these craft are withdrawn from class after leaving the builder's yard, quite a number remain classed throughout their life, and it is noted from the reports of subsequent surveys received in the London Office that the usual wear and tear takes place in those parts of the vessel which may be taken as similar to ordinary cargo vessels, e.g., shell plating, bunkers, and in addition considerably more wear seems to occur to the shell in way of the chain cables, which is due presumably to the greater number of times these vessels drop the anchor when on service.

Wear also appears to be found at the well-side plating, particularly at the lower strakes, and it would be interesting to know if Mr. Macleod has noticed any other places in these ships which are liable to deterioration, also whether he has considered any special provision with a view to minimising this local wastage referred to.

W. J. Roberts.

I should like, on my own behalf, to thank Mr. Macleod for his very interesting paper. The construction and operation of dredgers are subjects about which it is remarkably difficult to acquire authentic information, and I feel we are indebted to Mr. Macleod for his remarks.

I should like to ask Mr. Macleod one question. I know of one hopper barge in which the riveting of the decks and bottom gave trouble soon after the vessel went into commission. It was suggested at the time that abnormally large doors in the bottom were responsible for the weakness, because being so large they allowed the spoil to fall too rapidly, and thus caused the barge to jump severely when they were opened. It was argued that this imposed too severe stresses on the vessel's structure.

Although I have not any details of her structural arrangement, I believe she was reasonably well built, and while the weakness in the riveting could, I suppose, have be obviated by adopting a different and better design, I should like to know what Mr. Macleod thinks of this case, and in particular if he knows of any recognised ratio, adopted in practice, between the dimensions of the doors and the capacities of the hoppers and the buoyancy tanks.

CORRESPONDENCE.

G. R. Edgar (Greenock).

In his paper Mr. Macleod has described the main features of typical dredging plant, but, as he notes later, has not entered into the subject of scantlings. He refers to the substantial corrosion margins allowed for wear and tear, but, while this may be the case in this country, it is not, to the best of my knowledge, the same abroad. The chief dredger building country abroad is Holland, which not only builds, but also maintains, a large dredging plant at home and in the colonies, and to a smaller extent, Germany. It may be that the heavier scantlings adopted here are due to the margin stated, or it may be to a certain extent brought about by the type of ground to be dealt with, but it is worthy of note that in either case, from the point of view of an owner abroad, neither reason may appear particularly applicable nor the extra material necessarily desirable. For example, the need for heavy scantlings in a suction dredger operating in sheltered waters is not particularly apparent.

The chief wear and corrosion occurs, so far as my experience goes, in the well and hopper sides, while beyond this the chief features of repairs are the numerous small indents in the shell and many small items of deck damage resulting from the condition of service. Internally, given normal care, there has not appeared to be a great deal of corrosion, and I should be glad to know if this has been the author's experience.

I should like also to ask if hopper doors are sometimes made of steel and if particular care is taken with the fit of the edges. Where the edge of the door fits against a sloping surface a good fit could easily be maintained, but is particular attention paid to this part? It may not be necessary with certain kinds of spoil, but it would appear needful with mud, and certainly with silt. Is it possible to remove silt by allowing it to settle in the hopper, and if so, does it settle quickly enough to allow of continuous pumping until the hopper is filled with silt? Pumping water containing silt on to reclamation areas is one way of getting rid of the silt, but if there is no reclamation area, is it practicable to employ hoppers, in view of the large quantities of water to be dealt with and the fineness of the silt?

And finally, as the dipper dredger is not a common type is it used primarily on account of its ability to deal with heavy and difficult ground, and is it more able in this respect than a bucket dredger, or is it cheaper in first cost and upkeep?

REPLY BY THE AUTHOR.

Mr. Blocksidge refers to the preparation of dredgers for the voyage when being delivered from the building port, but it might be noted that under present conditions this has to be done to the satisfaction of the Board of Trade Surveyors, and the onus is not on the Society. As Mr. Blocksidge states there are many tricky points involved. In addition, the matter of stability should not be overlooked, particularly with the bucket type of dredger.

The question of depth of dredging raised by Mr. J. G. Buchanan is one on which one cannot be very definite, as for the most part dredging is undertaken to make or preserve a water passage for ships and the depth desired is consequently regulated by the size of vessel for which provision has to be made.

The draught of the "Queen Mary" approaches 40 feet and this gives an indication of a maximum for dredging depth. Thus a dredger dredging to 70 feet depth would probably be able to work to this maximum at all states of the tide, and this depth has been worked to by both ladder and suction dredgers. Though dredging has been done at this depth, the great outreach of ladder or suction obviously renders extreme lengths undesirable. A choice of type of dredger would normally be made after a consideration of the spoil to be dealt with, the site of the dredging and the disposal of the soil. Sand and material of a fine nature lends itself to suction, the grab type is handy for work about dock corners, but in most British harbours the bucket type is in most common use.

I cannot credit that Mr. Wm. Thomson has derived so much information from the paper as he professes, but it is hoped it has been found of interest. The variation in the scantlings adopted depends very largely on the margin desired for corrosion and wear and tear, which again depends on the amount of protection and care to be afforded later, so that apart from the parts of the vessel indicated in the paper at which strengthening is necessary on account of local loads, extra scantlings are largely a matter of opinion. Hopper sides are subject to a good deal of wear and are often made of shell thickness, and the same applies to hopper or centre keelsons. The plating taking the door hinges is also made thicker, about ·50 to ·60. The stiffening of the hopper side is usually supported by a strut to the side framing, but any other form of stiffening could be adopted, such as deeper stiffeners. The "strutted" stiffener is, however, the most usual.

Wear and tear is found on the hopper sides, keelsons and coamings, and on the sides of the bucket ladder well, but beyond that the wear and tear has not been found too excessive. The deterioration in the internal parts of the vessel is similar to that in ordinary ships and is dependant on the care devoted to the structure. Mr. C. Lloyd Roberts also refers to this question of deterioration, but I would not add anything more to the above except to observe that every ship, no matter of what type, may exhibit individual characteristics.

Mr. W. John Roberts refers to the size of hopper doors, but it is difficult to imagine how this could be a factor in the case he mentions, and I should think the cause of the trouble must have been elsewhere. So far as is known there is no ratio for door openings, which are generally kept as small as possible. Certain authorities may ask for a large opening to ensure the spoil will eject itself without assistance when the doors are opened, a matter also affected by the slope of the hopper sides.

Mr. Edgar is referred to the reply to Mr. Thomson and Mr. C. Lloyd Roberts, and it would appear that the heavy scantlings, particularly in the case he instances, is largely a matter of personal preference and scarcely of necessity.

Certain authorities insist on much heavier scantlings at well sides and in the hopper, and on the framing and shoots, whereas others engaged on similar work are content with normal scantlings.

With regard to the material of the doors some harbour authorities (the Mersey) have the hopper doors made of steel and this, too, may be a matter of opinion.

There is a great variation in the dredged silt ; some may be pumped out of the hopper for land reclamation as soon as discharged into the hopper, while some may necessitate continuous pumping and overflowing before a load is obtained. Hopper doors which require to be silt tight may require rubber facings to be fitted, but normally this is not required as the wood fitting chocks provide ample tightness for the ordinary dredged material. The fit of the hopper doors is, however, a matter which requires attention.

In conclusion, I wish to thank my colleagues who have favoured us with their criticism, but as the paper is no doubt more informative than controversial, a big discussion could not be expected.

NOTES ON RECENT DEVELOPMENTS IN LARGE PASSENGER SHIPS.

READ 6TH FEBRUARY, 1936.

PART I.—(a) STRUCTURAL.

BY S. TOWNSHEND.

INTRODUCTION.

At the time when the interest of everyone is focussed on the two largest, fastest and most luxuriant passenger liners which have hitherto been built, it is fitting that the Staff Association should arrange to have a paper prepared describing the developments which have taken place recently in vessels of this type. In choosing the title or subject of a paper and then selecting the authors, the Association has adopted a course which is somewhat unique in its own history, and a writer chosen under such circumstances feels at a disadvantage compared with previous contributors. He must interpret the title of the paper, he must decide what is meant by development and what is to be regarded as recent. He feels that he is put on his mettle, and must try and "deliver the goods." Such conditions would not perplex one who volunteers to prepare a paper because, whatever his knowledge may be, he can choose his own subject, name its title, treat it in his own way and limit its scope to suit his own capacity.

In the present instance the Committee has very considerately asked that the remarks be limited in length. The author has decided to deal principally with developments which have taken place during the last fifteen years, and not to enlarge upon those which lie in the category of passing vogue or fashion.

PROGRESS IN GENERAL DESIGN AND APPEARANCE.

If a vessel built, say, in 1920, be compared with a modern ship completed during the last year or two, it can at once be seen that a remarkable change has occurred in the general design. In the modern vessel low oval funnels of large fore and aft diameter and small rake have superseded tall slender raking funnels; the imposing array of large cowled ventilators on the superstructures has given way to carefully designed and unobtrusive, but effective air intakes; stems are made with considerable slope or curvature; the cruiser stern and its varieties have become almost universal; streamlining has been extended to erections and deck houses; superstructures have grown in height and length; and the closing in of promenade and airing spaces by means of screens has added to the massive appearance, which is still further emphasised by the apparently squat funnels.

Further, the craze for rapid mechanical movement has its reflection in the general appearance of the modern vessel, which is designed to convey an impression of speed and power. Even the popular and erroneous notion that fast ships must have more than one funnel has been pandered to again, and some large passenger vessels have recently been completed, in each of which three funnels are fitted, one being used for its normal function, whilst the others are used for housing respectively a first class companion-way and a deck store and ventilating room.

Many of the foregoing changes, although impressive and characteristic of the present time, are evolutions which represent the march of vogue and fashion more than structural advancement. Indeed, there are some who wonder whether these changes indicate any real progress, and their doubts are not alleviated by the knowledge that the "BREMEN," into which ultra modern ideas have been incorporated in regard to pear-shaped funnels, streamlined deck houses, Oertz rudder and shell butts facing forward, could gain no advantage in performance over her sister vessel, "EUROPA," which was fashioned on more conventional lines. If any difference does exist, the published records appear to be in favour of the "EUROPA."

Nevertheless, in many respects, the modern passenger ship, taken as a complete unit, undoubtedly represents a great advance, although progress in hull structure has not been so marked as in the machinery. Possibly this may be due to the fact that in the nature of things the hull does not offer the same scope for development as the machinery. This observation may need qualification when the real merits are established of such discoveries as Maier form, Arc-form and others, although, in this connection, it is well to bear in mind that the all-round performance of a ship cannot be judged solely by its behaviour in smooth water.

The last fifteen years covers a period during which marked progress has been made in details. Further, great prominence has been given to streamlining in various forms, as model experiments have revealed the substantial savings which can be effected in the region of the stern by designing the stern frame, rudder post and rudder on scientific stream lines, and a great variety of proprietary designs have been evolved.

ACCOMMODATION.

Many years ago a well-known naval architect said that "a builder may produce a ship possessing every virtue as regards perfect material and finish, but the material may not be so arranged as to prove a source of profitable revenue on the trade for which the ship is intended." Following this pronouncement, it was noted that several of the large shipping lines appointed their own naval architects to develop the ideas and designs which actual experience in trading suggested, it being left to the builders to incorporate them into a practical unit of construction.

Great progress in the development of passenger accommodation has been the natural outcome of such a policy. An improvement which has been introduced, particularly in large passenger ships of the Atlantic Liner and cruising types, is the allocation of much larger deck space per passenger, not only for the cabins, where the one-berth room with private bath room attached is so popular, but especially for the public rooms and recreation spaces. It is certain that the traveller of the future is to be well catered for in his social and sports life on board ship. These amenities are naturally costly, but experience has shown that rarely are all the berths occupied on the large vessels, and in these circumstances the deck space allotted to cabins is not being efficiently used. Better social accommodation will attract passengers and help to maintain a more stable condition of "carrying to capacity." It is obvious that a development of this kind must have many influences on the structural arrangements. For example, the necessity for providing large clear deck spaces suitable for dancing and games has introduced new problems in the pillaring and supporting of the beams of the decks above such spaces. Also, in order to avoid the obstructions caused by hatches on the superstructure decks, coamings have been fitted flush with the deck, or, alternatively, the hatchways have been terminated at a lower deck-level and cargo doors have been arranged in the ship's sides. In other cases lifts have been placed close to the ship's sides so that the cargo can be readily moved through the doors.

It is now usual to place the dining saloons low down in the hull, adjoining or close to the galleys, pantries and serving rooms. This frees deck space higher up in the ship which can be more usefully employed for public rooms or deck cabins, whilst, at the same time, greatly improved facilities can be provided in regard to the feeding arrangements. Structurally, also, there is an advantage because the large openings for the domes and galleries, usually cut in the deck over the saloons, can be located near the neutral axis of the ship and very little compensation for them is necessary. The foregoing remarks also apply in the case of swimming baths which are commonly placed low down in the ship.

In order to provide the extra height of 'tween decks required in way of the dining saloons, the sheer line of the deck is lowered and then gradually raised to the normal 'tween deck height clear of the saloons.

A common practice in large passenger vessels is to provide little or no camber to the beams on the lower decks, and to make the camber of the weather decks somewhat less than the standard usually adopted in smaller vessels. The reasons for such modifications are obvious and require no further comment here.

Certain architectural features involving lofty, unobstructed domes and roofs over the public rooms, have necessitated arched lattice interlocking girders being built on the top of the roof structure. In this way very large domes have been supported externally by comparatively light structures.

The increasing popularity of the cabin with private bath (or shower) and w.c. adjoining is now being catered for, and in recent ships a large number of cabins with such amenities have been fitted. These and other increased sanitary appliances require a great amount of piping and plumber work, and special consideration has to be given to the arrangements for same.

Proportions.

Two changes have become apparent in respect of the general proportions. The first is that with increase in size there has not been a proportionate increase in draught, due to the fact that limitations are imposed by the depth of water available at the terminal ports and ports of call. The tendency is, therefore, to produce a ship in which the ratio of draught to depth of structure is small. The influence of this feature on the longitudinal strength will be referred to later.

The second change is due to the fact that the old arguments in favour of low metacentric height and easy rolling condition are frequently being refuted by results in service, and the trend now is to build ships with greater breadth and finer block coefficient, which is being shown by experience to give better sea-kindliness in heavy weather.

The foregoing have enabled the ratios of length to depth of strength structure (L/D), and of length to beam (L/B), to be reduced whilst still retaining the desired conditions of stability, and the following table shows the trend in this respect since the time of the "Mauretania," viz.:—

Name of Ship.	Date of build.	L/B.	L/D.
Mauretania	1907	8·7	12·6
Olympic	1911	9·2	11·6
Berengaria	1912	9·0	10·8
Aquitania	1914	9·0	11·8
Majestic	1921	9·1	11·0
Columbus	1923	9·1	10·3
Ile de France	1926	8·3	9·5
Bremen	1929	8·6	11·2
L'Atlantique	1931	7·8	10·6
Empress of Britain	1931	7·6	9·4
Rex	1932	8·5	10·2
Conte di Savoia	1932	8·2	9·8
Manhattan	1932	7·8	8·9
Normandie	1935	8·2	10·5
Queen Mary	1936	8·2	10·4

It can be seen from the above table that the average L/D has dropped from about 11·5, prevailing about 20 years ago, to about 10 at the present time, whilst the L/B has been reduced from 9·0 to about 8·0.

Superstructures.

In vessels engaged on the North Atlantic passenger service troubles have been experienced in the topside material in way of the forward break of the first strength superstructure. This has been more noticeable when the break has been placed at about 25 per cent. to 30 per cent. of the length of vessel from the stem. To overcome this it has become a more or less general practice to carry the first strength

superstructure to within 15 per cent. to 20 per cent. of the length of the vessel from the stem. The second strength superstructure is set back from the first, and commences at about 25 per cent. of the length from forward. The tapering effect of such an arrangement is of great value in reducing local concentration or stress, and a similar principle is generally adopted at the after end of the superstructures.

This tapering principle is in recent vessels being further developed by making the front of the erections semi-circular or bow shaped. The prime idea is to reduce wind resistance, but there is also the advantage of still further reducing the stress concentration in way of the break.

In order to increase the deck space available for games and promenading, and to facilitate the lowering of the boats against a list, it has become a practice to extend the superstructures situated above the strength deck well beyond the moulded breadth of the ship. In some cases this extension commences at the strength deck and the stringer angle is fitted on the outside of the sheerstrake, the overhanging deck being supported by brackets about two to three frame spaces apart. It is usual to make only one step in the overhang, but in a recent large passenger ship the strength deck extended 2ft. 9ins., and the first superstructure deck extended 3ft. 6ins., beyond the moulded breadth, thus providing two steps in the overhang.

Side screens are commonly fitted over most of the length of at least one superstructure deck. These screens are equipped with large plate glass windows which can be lowered when required. Their construction is always a difficult problem, because, owing to their proximity to the sides of the hull they tend to participate in the main straining action of the ship which, by reason of their nature and the openings cut in them, they are scarcely able to resist.

Superstructures above the top strength deck still provide difficult problems in practice in spite of the investigations which have been made, and the very excellent papers which have been written, on the subject. The fitting of expansion joints to relieve the superstructures from participating in the main straining action of the ship has been adopted only to a limited extent. If there are two tiers of superstructures there is a greater concentration of stress at the strength deck in way of the joint, than when only one tier is fitted, and troubles have been met with at this part. Moreover, expansion joints add to the problems of the designer in arranging the lay out of the public rooms and cabins, and they only partially relieve the superstructures of stress transmitted from the main structure. Where lightness of superstructure is imperative then the expansion joint must be fitted, but otherwise, except in the very large ships, there is a recent tendency to eliminate the joint altogether and carry the strength deck right to the top superstructure deck. For example, in the "MANHATTAN" there are no expansion joints in the superstructures. The sun deck is supported by longitudinal beams, thus considerably adding to the strength and at the same time effecting an economy in weight.

In the larger vessels the tendency is towards raising the strength deck so as to leave as few tiers of light superstructures above it as possible. Considerations of stability may affect such arrangements, but stiffer structures and less noisy ones provide the compensation, and the modern trend, previously referred to, of building vessels with greater breadth and finer block coefficient, has made this matter of the raised strength deck more easy to develop.

MAIN STRUCTURE.

The complete change over from coal fuel to oil fuel, in large passenger vessels of the Atlantic Liner type, has made it possible to introduce a much better internal subdivision by arranging the oil fuel bunkers at the sides of the machinery space, which often extends over the midship half length. In this way longitudinal watertight bulkheads can be built continuously through the most vulnerable part of the vessel, and there is no need to perforate these bulkheads with openings as when coal is used as fuel. They are, of course, more strongly constructed than coal bunker bulkheads, and they enable the longitudinal strength of the hull to be better developed.

When such are fitted, it is possible to introduce a simplified form of construction at the bilge as adopted in the "MANHATTAN," where the longitudinal oil-tight bulkheads are carried down to the bottom shell, and the tank top plating of the double bottom extends only in the centre between the longitudinal bulkheads. In this way the usual troublesome break in transverse frame strength at the margin is

avoided. There is much in this arrangement which should commend it to builders and owners. A longitudinal cofferdam can be arranged in the double bottom parallel to the longitudinal bulkheads which can be used for pipe leads and for observation purposes.

In some vessels it has become a practice to fit a cofferdam over the tops of the oil fuel bunkers, forming a space of about three to four feet between the crown of the tanks and the deck next above. Such an arrangement has many advantages, especially when passengers are carried on the deck over the bunkers, whilst the cofferdam space is useful for accommodating the pipe leads. The arrangement also facilitates the connecting of the smaller tween deck frames to the larger hold frames, the brackets being arranged in the cofferdam, thus leaving a clear floor space on the deck above in the passenger accommodation.

In very large vessels with deep well-ventilated double bottoms, there is not the same necessity for the customary corrosion increases to be made to the structure in way of the boilers as in smaller vessels. Instead of the usual general additions ranging from ·04 ins. to ·10 ins., it has become a practice to add about ·10 ins. to the thickness of the tank top plating only, and to make little or no increases to the other members of the double bottom. Also, in these vessels, it is often unnecessary to provide the normal stiffening of bottom forward against pounding; firstly, because the size and draught of the vessels are such that the bottom can rarely, if ever, rise out of the water, and, secondly, because most of them are so fine in form that flat of bottom can scarcely be said to exist forward of the half length.

A development in respect of boiler uptakes was incorporated in the "MAJESTIC" and "LEVIATHAN," completed before the War. This is some time ago, and no claim is made that the development is recent, but it has been reverted to in the ill-fated "L'ATLANTIQUE," in the "BREMEN," "EUROPA" and "NORMANDIE," and was proposed in the two very large superliners designed for the United States Lines. It will be noted that all the foregoing are foreign built or designed. In these vessels the uptakes from the boilers are led up in casings fitted on each side of the ship, leaving a space at the centre between the casings of over 20 feet. Above the top superstructure the uptakes are led into the centre line and up through the funnels. The combined breadth of the deck openings for the divided uptakes is about 25 per cent. greater than the breadth of a single opening for the normal central uptakes.

The "MAJESTIC" and the "LEVIATHAN" sustained main structural failure in the strength deck and topsides, the fractures occurring in way of the fore end of the midship boiler casings in both ships, and also at the after end of the forward boiler openings in the "LEVIATHAN." Many reasons have been advanced to account for the failures. These vessels, some years after they were built, were converted for burning oil fuel, and, in the case of the "LEVIATHAN," a nest of oil fuel bunkers was arranged right across the ship at the fore end between the fore peak and the forward boiler room. This alteration increased the bending moment on the vessel much beyond that which had been originally contemplated, and represents a feature which would not now normally be adopted in a vessel of this size and type. In addition, there were local features in way of the damage which were undesirable. Large hoist openings were arranged in the deck at the forward inboard corners of the midship casings, and expansion joints were fitted in the superstructures at both the forward and midship casings. The foregoing, as well as the divided uptakes, were considered to contribute, in varying degrees, to the main failure. No doubt, if the importance of these points had been realised by those responsible for the original design of the vessels, a better arrangement would have been evolved.

The influence of the divided uptakes on the problem is not so simple to assess. It is reasonable to assume that the material of the strength decks at the centre of the vessel, inside the line of the deck openings, cannot be so effective in its contribution to the main structural strength as the material disposed nearer to the vertical members of the girder, represented by the ship's sides. The divided uptakes arrangement simplifies the lay-out of the accommodation, whilst the decorative value is enhanced by long vistas in the public rooms, which in the case of the "BREMEN" amounts to over 450 feet, and there is an economy in space in the lower parts of the hull. If, therefore, it is desired to adopt such an arrangement, it is thought that the material between the uptakes could be reduced in thickness, and a corresponding increase could be made to the deck material outside the line of the deck openings. Further, it might be advisable when making strength calculations, not to give full credit for the material inside the line of the divided uptakes, unless the strength of this material is reasonably possible of being fully developed in the ship's main girder by fitting effective longitudinal vertically disposed ties. The nature of the lay-out of accommodation rather precludes this being adopted.

The modern demand for speed has brought in its train the inevitable problem of vibration. It has, therefore, become more important to design the internal arrangements so that the proper pillaring of the decks is not interfered with. This is fully realised by the naval architect, but his views, too often in the past, have been ignored or subordinated to the opinions of the ship's architects and decorators. The result may have been a vessel having very attractive and distinctive architectural features which for a while, at least, were effective in "drawing a full house," but, once the newness has worn off, the regular passenger, who realises the great discomfort of undue vibration, seeks a more comfortable if somewhat less ultra-modern floating hotel. The importance of this matter is now better appreciated, and whilst the technical expert is increasing his knowledge and adapting it to the reduction of vibration, the owner is becoming much less insistent in his demands for vibration-encouraging architectural features. In fact, in one or two recent cases it is known that the owner, having heard of the difficulties which the decorator's designs were causing to the pillaring desired by the naval architect, has instructed the decorator to accept the pillars as necessary evils, and to exercise his ingenuity in making the best of it. This change in policy is very significant.

As a basis for minimising vibration in passenger vessels it has become a practice in regard to beams to adopt a standard of stiffness above that which would be dictated by considerations of strength only, and to avoid long spans by fitting more rows of girders and pillars. With the same objective in view it has been noted that a somewhat higher standard of stiffness and strength for deck girders has also been adopted in the larger high-speed vessels, but this is partly due to the fact that as the details of design and internal arrangement are developed it is found impracticable to adhere to a regular and even spacing of pillars, and it is better to arrange initially a surplus of strength in the girders so as to permit of a limited latitude in the spacing of the pillars. In some cases the deck girders have been 100 per cent. stronger than required for the normal standard spacing of the supports.

Without wishing to encroach upon the province of my colleague, who is contributing the machinery section, I would like to draw attention to the recent progress made in applying electric propulsion to ships. In its present stage of development, it is understood there are certain difficulties in the transformation of mechanical to electrical energy which cannot be avoided, but these difficulties are being overcome and may be eliminated. In the meantime, however, they apparently do not prevent the ship-owner from adopting a rotary and almost vibrationless drive, which is of such vital importance to the modern large passenger vessel.

The use of high elastic limit and special quality steels for the topside members has now become fairly general. The steels differ somewhat in characteristics and the reductions which have been permitted in the thicknesses naturally vary according to the properties of the steels and to the position they occupy in the ship. The high tensile steel used in the topsides of the "BREMEN" was heat treated after rolling, whilst all holes were drilled instead of punched and the edges were planed after shearing. The reductions in the thicknesses ranged from 10 per cent. to 12 per cent., and it has been stated that an economy of 800 tons was effected. In the case of the "REX," high tensile steel represented almost 75 per cent. of the total weight, and the reductions in thickness compared with mild steel ranged from 6 per cent. to 13 per cent., the latter figure being applicable to the thick topside material.

It is of interest to note that the "NORMANDIE" is longitudinally framed on the bottom and tank top and also at the two uppermost strength decks.

STEMS AND STERNS.

A bow form which has found favour in recent times is the "Maier" bow, which is characterised by triangular body sections, a pronounced sharp rise of keel forward and an overhanging stem. It is claimed, in the case of a passenger liner of 30,000 tons displacement, that by lengthening the water line by only 4 per cent. and reconstructing the bow on the Maier form, a speed increase of two knots can be obtained with the same power as before. This claim seems rather optimistic, and here again it may be that the results in service will depend very much on all-round conditions and on speed in relation to size of ship. Very good results have been obtained, but unfavourable reports on the Maier form in heavy weather are not unknown.

A recent introduction to merchant ships is the bulbous bow. Investigations and experiments which have been made regarding the effect upon the resistance to propulsion of bulbous shaped sections

at the fore end below the load water line indicate, for still water conditions, a definite reduction in propelling power at the higher speeds, ranging from 5 per cent. to over 10 per cent. There is little difference in resistance at the low and intermediate speeds. As these speeds are relative and not actual, it follows that the size of the ship is a criterion also of the influence of the bulbous sections, but, broadly stated, the higher the speed the greater can the bulb be made.

The best form of bulb is pear-shaped with a section flat at the bottom. Bulbous bows are fitted to many modern vessels, and the performances of these vessels on speed trials appear to indicate satisfactory results. But the question as to whether the gains can be held under all conditions of sea, especially the heavy weather condition, is not certain, and it is significant that the "QUEEN MARY" has been built with normal form at the fore end, below the load water line. It is known that tank experiments made in waves with models having a bulbous bow do not give such favourable results as in still water.

From the structural standpoint the bulbous bow, though somewhat unconventional in appearance, presents no unusual difficulties. Floors of normal depth and thickness are fitted, the frames are of peak bulb angles, and plate stringers are fitted at the normal spacing, supported by panting beams and brackets. Practical considerations running contrary to theory in this case, make it advisable not to design the bottom of the pear-shape too flat, especially in the smaller vessels. The locally full form at the bow, below the waterline, provides better access for riveting during construction and for upkeep and repairs afterwards, factors which always present difficulties in passenger vessels having fine ends. The convex shape of the bulbous bow gives added strength, both transversely and longitudinally, as compared with the normal flat sides in vessels of fine form, but experience has shown that the narrow hollow from above the bulb is not immune from damage. This part appears to act as a trap for quarter seas, and some additional strengthening has been necessary.

It is not inappropriate to refer to the practice—certainly not a recent one, but one which is becoming increasingly popular—of forming the upper part of the stem with steel plates bent to a radius which is small above the waterline and increases towards the top deck. At one time this arrangement would have offended conventional taste, but, in effect, the appearance is not unpleasing, and if a nicely designed medallion or crest be placed on the upper part, the result can be most attractive.

This type of construction provides the advantage of a more accessible bow and a bigger working platform around the anchor gear on the top deck. The fashion plates are usually slightly thicker than the end shell plating and are supported by breasthooks. Alternatively, the breasthooks have been omitted and the thickness of the plates has been increased. The lower portion of the stem is made of a forged or rolled steel bar or a casting, and its scarph with the plated portion is placed above the load line. If the fore peak be used as a water ballast tank, the caulking of the fore end can more easily be attended to with the built up construction than with the bar stem.

It is interesting to note that the stem of the "NORMANDIE" has such a pronounced curve forward at the upper part that it approaches closely to the old clipper type stem.

The stern of the "NORMANDIE" represents something quite new in large passenger ships. The lower part approaches the old "pea" shape, but at the deck below the top deck the outline changes abruptly and slopes forward after the manner of the bulwark of a tug. The result is quite pleasing to the eye. Mooring is done from the second deck. An anchor is carried at the centre line in a hawsepipe—likewise at the bow.

DETAILS.

There are several developments in details which have gradually established themselves and become common practice during recent years. They are, however, not confined to large passenger ships but are fairly distributed over the whole range of ships. For example, there are steel hatch covers, flush hatchways, beams underjoggled in way of the seams of deck plating, pipe tunnels, streamlined rudders, rudder posts and propeller posts, various anti-rolling devices in lieu of bilge keels, and last but not least, the substitution of electric welding for riveting in many items of non-structural importance. The foregoing are well enough known to warrant no further reference here. There are, however, one or two developments which it is thought well to refer to.

The fitting of shell plating with butts facing forward was adopted in the "BREMEN" and in the under water portion of the "REX" and "CONTE DI SAVOIA." It is understood that the arrangement

has also been introduced into some earlier Italian-built vessels. It is claimed that the avoidance of the eddies which arise behind the normally arranged shell butts represents an appreciable gain in resistance, but it is not yet certain that this claim has been fully established by results in service.

Another development which will be much appreciated by harbour authorities, comprises a proper sewage system whereby the discharges from sanitary appliances, baths, etc., are led to centrally disposed collecting tanks which, when full, are automatically discharged below the water. The advantages of such an arrangement are obvious, especially in the case of vessels having a large complement on board.

The large passenger ship, with its higher standard of comfort, would require a very great number of ventilators and ventilating shafts. To meet the demand for unobstructed decks, special arrangements for ventilation and air-conditioning have been devised whereby an almost complete absence of cowl ventilators has in some cases been secured. The air is taken in through special louvres which conform to the general design and contour of the structure, and which give access to ventilating shafts, down which the air is drawn to the various fan-rooms where it is cleaned, humidified and heated as necessary. Trunks are led to the accommodation, and the cabin passenger has under his personal control the quantity, temperature and direction of the air supply. In the public rooms the air-conditioning is maintained automatically. In a large vessel recently completed for Eastern trading the air-conditioning of the whole of the accommodation has been successfully undertaken.

Longitudinal Strength.

It is thought that these notes would not be complete without some reference to the question of longitudinal strength. It does not appear that there has been any well defined standard of longitudinal strength for very large passenger ships. Analyses of the section moduli of these vessels reveal differences which cannot be reconciled with the recognised variant of bending moment, whilst analyses of the bending moments, which have been calculated under the usual standard assumptions, do not possess the generally accepted relationship to the recognised variants of displacement and length.

There are at least two principal reasons for these discrepancies. Firstly, there is the influence of the personal element, whereby the designer exercises his own opinion as to a suitable stress value. This factor of the personal element has produced ships of similar character having dissimilar stress values, and it is difficult to decide that one ship is unnecessarily stronger than another until very careful consideration has been given to the nature of the service, and to the condition and behaviour of their structures after several years of actual operation. The second principal reason for the discrepancies is due to the fact that the small ratio of draught to depth of structure, which these modern vessels have, disturbs the usual balance between distribution of weight and buoyancy which is possessed by normal ships in which draught is a greater ratio of the depth.

Mr. W. M. Balfour, in his paper "Strength of Ships," read to this Association in October, 1933, expressed his doubts as to whether the usual empirical formula for maximum bending moment took account of all the necessary factors, and by very ingenious reasoning he deduced that the section modulus is a function not only of draught but also of depth of ship to the strength deck.

Investigations which the author has made regarding the strength of large passenger ships, in which draught is small compared with principal dimensions, indicate clearly that bending moment does not vary in direct proportion to draught, but increases relatively as draught compared with depth of structure is reduced. This conclusion was reached by Mr. Balfour independently, without any previous knowledge of these investigations.

The analyses also indicate that bending moment does not vary in direct proportion to displacement coefficient, but varies as the product of the displacement coefficient and a factor which is less than unity, whilst a substantial positive bending moment appears to exist at zero displacement coefficient. Investigators have already asserted that bending moment does vary directly with displacement coefficient, but in their calculations the type of the vessel was kept constant, whereas in actual practice the type always changes with change in block coefficient.

The analysis of stress values was not a simple matter and great difficulty was experienced in finding uniformity in values, even after giving consideration to design, speed, service and personal element. Indications seem to point to the fact that speed was the dominant factor. A ship driven at a high speed

experiences greater dynamic stresses than one driven at a low speed, whilst the fast ship will in the course of its life meet many more alterations of stress than the slow one. In cases where speed is the only variant it is found that when $\sqrt{\frac{\text{speed}}{L}}$ exceeds ·80 the value of $\sqrt[3]{\frac{\text{stress}}{L}}$ should be reduced.

The evaluation of section moduli based upon the analyses of bending moments and stress values gave results, the general characteristics of which were in general agreement with those obtained by Mr. Balfour.

The longitudinal strength of the modern large passenger ship is undoubtedly increased above that obtained by extrapolation of the recognised standard, and it appears that this increase is necessary on account of the small ratio of draught to depth of structure and on account of the higher speeds.

Conclusion.

If one may look back on his own notes and criticise them, the author would refer to the remarks on bottom construction forward, under the section "Main Structure." It may be that what is written there might create the impression that the sea-service of the large passenger ship of fine form and fast speed is less severe, relatively, than in the smaller, fuller and slower vessel. This is not so. A photograph of a large passenger ship, over 760 ft. in length, taken in heavy weather in Mid-Atlantic from the deck of another very large vessel, shows the former ship pitching into a head sea which has risen to the level of the forecastle deck and is about to break on board. The potential danger of a heavy sea breaking against the deck structures of a large vessel, having great mass and high driving power behind them, must not be underestimated. There is ample evidence of damage caused in these circumstances.

Moreover, when one reads of the statements made by the masters of ordinary ocean-going cargo ships, that, during the severe gales of the winter of 1934–35 solid seas were met with which reached to the height of the hounds of the foremast, or swept aft, carrying away engine room ventilators, skylights and other structures on the boat and navigating bridge decks, one must admit that it is possible to meet waves, the heights of which greatly exceed those ever recorded by official observers, and against which even the great freeboard at the bow of an Atlantic liner could not provide effective protection.

The bow of the "Normandie" affords indirect evidence of the truth of this point, in so far as the forecastle deck is formed into a kind of whaleback having a substantial breakwater at the after end, the whole arrangement comprising a somewhat unique feature in a vessel of this type and size.

It is realised that there are some recent developments regarding which the author has been unable to secure sufficient information, and there must be many developments which have not come under his notice. It is hoped, therefore, that the Members of the Association who have been closely associated with the type of ship under consideration, will contribute their knowledge in the discussion on the paper and so improve its usefulness.

PART I.—(b) PROPELLING MACHINERY.

By R. LEE ANNEAR.

The history of the post-war period exhibits first a boom, followed shortly by a deep depression in shipbuilding. The handing back of passenger vessels which had been used as transports, a brief period of activity as nationals were repatriated, the passing of immigration laws restricting the number of aliens which would be admitted to countries which had previously welcomed emigrants, the promotion of cheap tourist trips, were all factors in the demand for economical types of propelling machinery.

The principal features to be noted in the development of the propelling machinery of modern passenger vessels, comprise the displacement of coal by oil for fuel purposes, and the extension of the use of electricity for power. Considerable experience of the convenience of oil for fuel was gained during the war. Labour troubles in colliery districts throughout the world threatened the supply of bunker coals. Oil fields were discovered in many parts of the world. Special tankers were constructed and stocks maintained to enable vessels to obtain oil fuel at all the principal ports. The result is that whereas in 1914 about 90 per cent. of the sea-going vessels used coal, in 1934 only about 52 per cent. used coal and 46 per cent. used oil for fuel.

In the case of passenger vessels, the more uniform performances of the engines using oil as fuel, the time taken for bunkering, the dirt and expense accompanying the operations of coaling and discharging ashes, the possibility of saving space by using the ballast tanks for fuel, the 35 per cent. higher calorific value of oil compared to coal, were all reasons which led to this supersession of coal by oil.

In the case of steam engines there has been a considerable increase in the steam pressures, which have risen from about 220 to about 450 pounds per square inch generally. This has been effected by the more general use of water-tube boilers of various types.

In a few exceptional cases Benson, Loeffler or Sulzer Monotube boilers generate steam at pressures of 800 to 1900 pounds per square inch. The heating surface necessary in the case of these rapid-circulating units has been reduced to a little more than one square foot per shaft horse power. Superheaters are used, which raise the steam to temperatures of 650°/850°, their superheater heating surfaces amounting to from 13 per cent. to 25 per cent. of those of the boilers.

Ten years ago about 2000 shaft horse power was the output of a single boiler. The "Rex" has twelve water-tube boilers and a shaft horse power of 120,000.

The vessels are usually fitted with forced or induced draught systems having air pre-heaters. The latter have heating surfaces of an area in some cases equal to 90 per cent. of the combined boiler and superheater heating surfaces.

The feed water for these installations is distilled, de-aerated and heated to 300° F. and sometimes more, and forced into the boilers by pumps of high pressure type.

Modern condensers are of the regenerative type in which the condensate is maintained at a temperature approximating that of the exhaust steam. This is effected by making the exhaust steam pass through the condensate. The air is drawn off from the upper section of the condenser by means of a steam ejector. The condensate is passed through a direct-contact de-aerator to the feed tank. Thence the feed pumps extract the feed water, pass it through the feed heaters to the boilers.

The average coal consumption in pre-war installations rarely fell below $1\frac{1}{2}$ pounds per horse power per hour, but with oil fuel and superheated steam, consumption has been reported as low as ·57 pounds of fuel per horse power per hour.

The increased economy due to the superheating alone has been shown in coal and oil-fired boilers to be over 12 per cent.

Another modern method of making steam engines of the reciprocating type more economical is the addition of an exhaust-turbine, driven by the steam from the low pressure cylinder exhaust and coupled to the main propelling shafts by either mechanical gearing, or with the turbine driving an electric generator which supplies current to a motor on the propelling shaft. It is stated that about 24 per cent. economy has been obtained by fitting a Bauer-Wach exhaust turbine.

In another system the exhaust steam turbine is made to drive a turbo-compressor, through which the steam exhausted from the H.P. cylinder is compressed before passing to the intermediate pressure cylinder.

The use of poppet steam and exhaust valves with cam driven gears has improved the steam reciprocating engine by making the steam passages easier.

For passenger vessels driven by steam, geared turbines or turbo-electric engines are adopted where high speeds are necessary.

The propellers of modern passenger liners are constructed of bronze. In general, they are cast solid and the "Aerofoil" design has been adopted in many cases. It is customary to test the suitability of a design by making tank experiments with a model of the vessel's form.

There has been a large increase in the practice of electric welding for work on passenger vessels. In the construction of condensers, oil and air coolers, tanks, ventilating trunks, boiler-casings, auxiliary engine seatings, exhaust trunks for diesel engines and for many other purposes, it has been adopted with excellent results.

The use of aluminium has resulted in the pistons and liners of scavenge pumps, splash covers for crank casings and similar parts being lighter and hence more readily handled.

Many of the centrifugal pumps are of the vertical spindle type and are electrically driven. This has resulted in a saving of space on platforms. Considerable attention has been given to the question of arranging spaces for ensuring accessibility to auxiliaries and main engines when opening up for repairs and examination. Attention is also given to the ventilation of machinery spaces so as to avoid, as far as is practicable, pockets of inert air being formed in which oil fumes might create an atmosphere of danger. The provision of fire-fighting appliances which are available for coping with outbreaks of fire in every part of the machinery spaces, is made with every precaution so that the appliances can be brought into operation expeditiously at the seat of the fire. Portable foam-fire-fighters are located on the various platforms, and there are often large fixed plants with sufficient length of hose to reach any part of the spaces in which they are fitted. There are in most passenger vessels' engine rooms special telephones communicating with the bridge, and indicators are arranged to enable the officer on the bridge to see the direction of rotation and relative speed of the main engines. The latter form a valuable auxiliary to the engine room telegraph, and show how speedily commands are responded to by the main engines. Electric telegraphs are also available which ring continuously until the order is correctly acknowledged by the engineers.

The light signals in the engine room of a modern liner form a last important part of the control apparatus. Each electrically driven pump is signalled by a notice "Working," which lights up when the pump starts. Many of the oil lines have visible sight-feed boxes and the lubricating oil pumps' delivery and return leads are usually fitted with glass panels lit from one side enabling the flow to be observed.

Service oil tanks are fitted with float meters and built-in bunker tanks have a system whereby the overflows drain to a single tank, which, when partly full, is provided with a warning electric bell to avoid over-pressing of the system. Usually a system of pressure gauges of the "teledep" type are fitted for measuring the oil contents of the various bunkers. Boilers, fitted for burning oil fuel or waste heat gases, on an upper deck are controlled by distant pressure and water gauges from the working platform.

The convenient disposition of pressure gauges, thermometers, alarms and indicators is most important, some having to be local and others having to be visible or audible from the starting platform.

Thermometers of the "Thermocouple" type are widely used for indicating funnel and exhaust gas temperatures, and CO_2 recording meters are available for indicating the efficiency of the combustion of fuel.

In regard to the materials from which the machinery is constructed, it is to be noted that special steels are now available. Nickel, chrome, molybdenum, tungsten, copper, aluminium and silicon added in varying proportions have given special properties to the metal. Thus high-tensile, non-corrosive, heat-resisting and other properties may be obtained for increasing the length of service of the parts. For

the pinions of gearing, blower wheels of Buchi type blowers, cylinder covers and piston heads, blades for high-pressure turbines, superheater headers and tubes, there are special steels which are selected for their resistances to the particular stresses to which these parts are subject. There is great care needed in the working of these steels, and upon the final heat treatment depends the suitability of a particular metal for its purpose. A very complete account of these steels is given in "Steels in Marine Engineering," by T. H. Burnham, I.Mar.E., Feb. 1934.

Condenser tubes have latterly been made of copper-nickel mixtures which withstand the corrosive and erosive action of the high-speed flow of ærated circulating water.

Aluminium has also been used with copper, and although not with such good effect as copper-nickel, the copper-aluminium tubes have proved much more efficient than the copper-tin-zinc tubes which were in use before the war.

Greater care is being exercised in obtaining suitable mixtures for cast iron. There have been improvements both by the additions of nickel, chromium and other metals to the iron, and also in the preparation of moulds, and in the heat-treatment after casting.

Anti-friction metals for bearings are also of great importance in the modern passenger liner's engines, and methods of tinning cast steel bushes to obtain uniform adhesion of the metal over the whole surface of the bush are the subject of experiments. The tendency of the white metal to fracture in connecting rod top and bottom end bearings makes the problem of adhesion in the case of internal combustion engines one requiring primary attention.

There are lubricating oils on the market of many grades and suited for various work, but in forced lubrication systems one of the essentials is that dirt and water should be extracted from the oil, and in modern practice filters and oil purifiers are provided for this purpose. The filters are usually arranged in batteries, so that the oil can be kept flowing through another filter while one filter is in process of clearing. This is usually provided for by arranging that after the oil is passed through the engines it is collected in a special dirty-oil tank from which it is drawn, passed through the purifiers and filters, and thence to a purified-oil tank for supply to the engines.

In some internal combustion engines there are air coolers, through which the air from the crank casings is drawn. The oil vapour is deposited on the cooling surface and thus extracted from the hot air.

The general practice latterly has been to separate the auxiliaries from the main propelling machinery and drive them independently.

In steam reciprocating and turbine driven vessels and in motor driven vessels constructed some years ago, the pumps, not driven directly from the main engines, were steam driven.

The feed pumps and, in general, the air pumps of turbine driven installations are steam driven independent units.

Most of the auxiliaries in recent vessels are electrically driven. In some steam vessels and in most motor driven vessels the electric generators are driven by oil engines. The "STATENDAM" was an early illustration of this system.

The convenience of being able to vary the load according to the requirements for current, without interfering with the main propelling machinery, and the suitability of oil engines for supplying power for port use, have made the arrangement popular.

In the case of the motor vessel "BRITANNIC," the main air compressors are driven by independent diesel engines. The other auxiliaries are electrically driven. Of the 2075 kilowatts generated, 850 kilowatts are for driving the machinery auxiliaries excluding deck machinery and lighting.

The great importance of the electrical plant in the modern passenger vessel may be judged from a comparison of the power required for main propulsion with the capacity of the electrical generators.

Year.		S.H.P. of Main Engines.	Kilowatts.
1927	BERMUDA	13500	1272
1928	STATENDAM	19500	1600
1929	ULSTER MONARCH	6500	337
1930	BRITANNIC	20000	2075
1931	REINA DEL PACIFICO	22000	1450
1934	ASTURIAS	24000	1915
1935	DUKE OF YORK	9000	315
1935	DERBYSHIRE	8000	320
1935	NORMANDIE	160000	13200

A number of liners constructed during the period 1918-25 were propelled by geared turbines. To take advantage of the efficiency of the small diameter turbine when run at high speeds, and to avoid the troubles due to cavitation experienced with propellers driven at these speeds, double-reduction gearing was utilised.

The design and manufacture of this form of gearing presented many difficulties, and other forms of gearing have since been adopted. Single-reduction gearing is usual, but in a number of notable instances turbo-electric machinery has enabled very high powers to be transmitted from fast running generators to comparatively low speed motors. The Vulcan hydraulic transformer with single-reduction gearing was introduced as a solution of this problem. It was used in the installation fitted in the "TIRPITZ," afterwards called the "EMPRESS OF AUSTRALIA." In the original design the boxes containing the turbine elements of the clutches were filled with water. Oil was later substituted as the medium. On a shaft coupled to the engine crankshaft are mounted the primary impellers separated at a convenient distance from each other, and having blades set at contrary angles. The pinion, driving the main wheel to which the propeller shafting is coupled, is mounted on a hollow shaft, at the two ends of which are the secondary vanes. The pinion shaft rotates in the spaces between the primary impellers. The casings are filled by a centrifugal pump.

Some vessels propelled by internal combustion engines are fitted with this form of gearing. The engines, as in the case of electrical propelling machinery, can be non-reversible.

The hydraulic clutch has been used for making the flexible coupling between the Bauer-Wach turbine and the main shafting in vessels where this exhaust steam turbine has been installed. For this purpose the Vulcan clutch has proved a flexible and convenient fitting.

During the post-war period there have been several interesting conversions, having the purpose of increasing the speed or economy of the engines of passenger vessels. One reported case, the "STAVANGERFJORD" of Stavanger, a twin screw quadruple-expansion engined vessel, 13,156 tons gross register, was thus improved. The vessel has eight single-ended boilers working at 220 pounds per square inch, and the steam is not superheated. The engines indicated 10,400 H.P. at 92 revolutions per minute, and the fuel consumption was 1·1089 pounds per indicated horse power per hour, giving the vessel a speed of 16½ knots. It was decided to fit Bauer-Wach reaction turbines, having double-reduction gears and Vulcan hydraulic couplings to transmit power to the main shafts. After the alteration, the engines developed 17,000 I.H.P. at 106 revolutions per minute. The fuel consumption was ·789 pounds per I.H.P. per hour, and the speed of the vessel increased to 18·35 knots. Over six round voyages between Europe and the United States, the average speed increased from 15·94 to 17·63 knots, and the consumption was reduced by an average of 193 tons of fuel oil per voyage.

Owing to competition on their trade routes it was found necessary to convert the Royal Mail vessels "ASTURIAS" and "ALCANTARA," of Belfast, to increase their speed. These vessels were originally fitted with 4 S.C.D.A. internal combustion engines and twin screws. The engines developed 14,500 B.H.P. and gave a speed of 16 knots. It was decided to replace the main propelling motors by turbines supplied with steam from three Johnson water-tube boilers.

The main motor room of each vessel, after removing the original propelling machinery, with the compressors and air reservoirs, was divided into turbine and boiler rooms by a screen bulkhead built at the forward end. There was sufficient beam to accommodate the three boilers abreast and allow for the necessary passages. The boilers are constructed for a working pressure of 450 lb. per sq. in., and are fitted with integral superheaters to give a temperature of 750°F. The air supply is maintained by electrically driven forced and induced draught fans. A Ljungstrom-Howden preheater is driven in the funnel base by an electric motor, and this recovers heat from the funnel gases and passes it to the air currents supplying the boilers.

All the steam generated passes through the superheaters, and the degree of superheat can be modified by butterfly air valves, which direct more or less of the hot gases through the superheat sections. Each boiler has seven burners for injecting the fuel.

The turbines are of the Parsons impulse-reaction type, having H.P., I.P., and L.P. driven pinions on each main gear wheel. The condensers are of the regenerative types and are underslung beneath the L.P. turbines. They are consequently wide and rather shallow. The original line shafting is retained, but new solid bronze propellers are fitted 17 ft. 6 in. diameter, and 15 ft. 6 in. pitch, to suit the higher speed of the turbines.

The turbines develop about 24,000 S.H.P. at 140 revolutions per minute and a speed of 18½ knots can be maintained.

Some examples of modern passenger vessels with turbine machinery are appended.

The "KING GEORGE V," built in 1926, 789 tons gross, introduced the high pressure steam boiler in this country for passenger vessels. Fitted with twin screws and Parsons' single-reduction geared turbines, the engines developed 3,500 S.H.P. at 570 revolutions per minute. The boilers were of the Yarrow water-tube design and had a working pressure of 550 lb. per sq. in., and the steam superheaters were designed for 750°F.

In 1928, the "DUCHESS OF BEDFORD," of 20,123 tons gross, was constructed with twin screws driven by single-reduction geared turbines developing 20,000 S.H.P. The six Yarrow type water-tube boilers have a working pressure of 370 lb. per sq. in., and the steam is superheated to 680°F.

Built in 1929, the "STATENDAM," 29,500 tons gross, is a twin screw liner, driven by single-reduction geared turbines developing 19,500 S.H.P. at 125 revolutions per minute. The six boilers are of the Babcox & Wilcox type, and are built with solid forged steel drums. The pressure is 430 lb. per sq. in., giving an initial pressure at the turbines of 398 lb. per sq. in. The steam is superheated to 662°F. Steam is bled from the intermediate and high pressure turbines for feed-heating, and the consumption of oil fuel for all purposes is ·619 lb. per S.H.P. per hour.

In the same year the "BREMEN," of 51,656 tons gross was built. A quadruple screw single-reduction geared turbine installation, the S.H.P. is 120,000 at 180 revolutions per minute. There are 20 water-tube boilers at a pressure of 330 lb. per sq. in., and the superheat temperature is 660°F.

The "VICEROY OF INDIA," of 19,627 tons gross, was built the same year and was the first large passenger electrically driven vessel built in this country. There are two screws and two alternator sets, each of 11,600 kilowatts, giving a total shaft horse power of 17,000. The voltage of the alternators is 3,000. The alternators run at 3,000 revolutions per minute and the propelling shafts at 125 revolutions per minute. Six Yarrow water-tube boilers have a working pressure of 400 lbs. per sq. in., and the superheat temperature is 725° F. Three-stage feed heating is effected from the 15th, 13th and 9th stages of the turbines, and the temperature at which the feed water reaches the boilers is 300° F.

The "EMPRESS OF JAPAN," of 26,032 tons gross, was constructed in 1930. This is a twin screw liner of 30,000 S.H.P., developed by single-reduction geared turbines. The steam is supplied by six Yarrow type water-tube boilers with a working pressure of 425 lbs. per sq. in., and the steam is superheated to 700° F.

In 1931, the "EMPRESS OF BRITAIN," of 42,348 tons gross, was constructed. This vessel has four screws, and is propelled by single-reduction geared turbines. The total S.H.P. is 63,000, and of this the inboard turbines develop 42,000 S.H.P. and the propellers are driven at 150 revolutions per minute, the outboard turbines develop 21,000 S.H.P. and the propellers are driven at 200 revolutions per minute. Steam is supplied to the inboard turbines by six Yarrow water-tube boilers, to the outboard turbines by two Yarrow and one Johnson water-tube boilers, all having a working pressure of 425 lbs. per sq. in., and the superheat temperature is 725° F. For auxiliary purposes there are two cylindrical multitubular boilers, which give steam at 200 lbs. per sq. in. An oil fuel consumption of ·57 lbs. per S.H.P. per hour has been reported.

The turbo-electric "MONARCH OF BERMUDA," 22,424 tons gross, was built in 1931, a quadruple screw liner. Two turbo-alternators, each of 7,500 kilowatts at 3,000 volts pressure, give 18,600 S.H.P. The screw shafts rotate at 150 revolutions per minute. Steam for the Parson's turbines is supplied by eight Babcock & Wilcox boilers, with a working pressure of 400 lbs. per sq. in. and a superheat temperature of 675° F.

The same year another turbo-electric liner, the "STRATHNAVER," 22,285 tons gross, was constructed. This vessel has twin screws. The two turbo alternators at 3,000 volts give 28,000 S.H.P. at 125 revolutions per minute. Steam is supplied from four Yarrow water-tube boilers at 400 lbs. per sq. in., superheated to 725° F.

The "L'Atlantique," 42,512 tons gross, was also built in 1931. The four screws were driven by single-reduction geared turbines, having a S.H.P. of 45,000, supplied with steam from 16 double-ended boilers at a pressure of 227 lbs. per sq. in. and with a superheat temperature of 644° F.

In 1932, the "Rex," of 51,062 tons gross, was built. Fitted with single-reduction geared turbines, there are four screws. The shaft horse power is 120,000. Steam is supplied by 12 water-tube boilers at 384 lbs. per sq. in. pressure, and the superheat temperature is 716° F.

A sister ship, "Conte di Savoia," of 48,502 tons gross, is also fitted with single-reduction geared turbines and four screws. The shaft horse power is 100,000. Ten Yarrow type boilers supply steam at 425 lbs. per sq. in., and the superheat temperature is 725° F. This vessel is fitted with three gyro-stabilisers in a compartment, at a level with the waterline, just forward of the bridge. The casings stand fore and aft. This is the first large installation of this type of anti-rolling machinery to be fitted.

The "Normandie," of 79,000 tons gross, built in 1935, has four screws driven by turbo-electric engines of 160,000 S.H.P. There are four turbo-alternators, working at 5,000 volts and 1,000 revolutions per minute. The propellers rotate at 120 revolutions per minute. Steam is supplied by 29 Penhoet boilers, at a pressure of 400 lbs. per sq. in. and is superheated to 662° F.

The "Scharnhorst," 18,184 tons gross, is a twin screw liner fitted with turbo-electric engines of 26,000 S.H.P. at 130 revolutions per minute. The alternating current is supplied at 3,120 volts. There are four Wagner-Deschimag boilers, which supply steam at 711 lbs. per sq. in. superheated to 880° F.

The "Strathmore," 23,428 tons gross, is a twin-screw liner with single-reduction geared turbines. The shaft horse-power is 24,000 at 112 revolutions per minute. There are six Babcock & Wilcox boilers which supply steam at 450 lb. per sq. in. and the superheat temperature is 725° F. The turbine revolutions are 1,715 per minute.

The cross-channel passenger steamer "Duke of York," 3,743 tons gross register, is a twin-screw vessel with single-reduction geared turbines. The shaft horse-power is 9,000 at 250 revolutions per minute. There are four Babcock & Wilcox boilers which supply saturated steam at 225 lb. per sq. in. These boilers are coal-fired with Erith-Roe mechanical stokers driven by electric motors. The gears are cut to the new standard involute form termed the "all addendum." In this the shape of the teeth is such that the working surfaces are outside the pitch circle. The teeth are thus only engaged in contact through the arc-of-recess, and the sliding contact is all in one direction. (Fig. I.)

The Diesel or heavy-oil internal combustion engine has been widely adopted for the propulsion of passenger vessels. As facilities for obtaining oil fuel improved, the demand for this type of prime mover became more general. During the last twelve years there have been constructed engines which exemplify almost all stages of growth of the Diesel engine.

The four-stroke single-acting engine, using air-injection and having air compressors, circulating water, fuel, lubricating oil pumps and other auxiliaries driven by the main engines, was an early design. The double-acting engine then emerged and some of the auxiliaries were driven independently. The adoption of solid injection, and later the Buchi blower driven by the exhaust gases and discharging air at a pressure above atmospheric pressure, together with the waste-heat boiler for reclaiming some of the heat discharged with the exhaust gases, all marked the progress of the advance towards the ideal economy.

Almost contemporaneously, builders of the two-stroke-cycle engine brought out their designs firstly for the single-acting engine with air injection, then for the double-acting engine. Various methods of scavenging and different methods of cylinder and piston cooling have been tried. Solid injection of the fuel is now general. The Doxford or Junker engine has been among the successful two-stroke-cycle group. In this engine the combustion takes place between two pistons which, moving apart in opposite directions, actuate the crank shaft by means of three cranks to each cylinder. The centre crank is attached to the lower piston, and the two side cranks are attached by a yoke to the upper cylinder.

In the Burmeister & Wain two-stroke-cycle engine the exhaust valve is a piston which, through spindles and connecting rods, turns a layshaft connected by a chain gear to the main crankshaft.

Some of the vessels have had high speed engines with mechanical gearing; others are fitted with Vulcan hydraulic transformers.

The general adoption of the solid injection of fuel oil, the improved methods of scavenging, the more general supercharging and the utilisation of the heat from the exhaust gases for generating steam, are all measures which have increased the economy of the propelling engines of the internal combustion types. The reduction of the weight of internal combustion installations has been approached from many directions.

In addition to the other methods are some ingenious designs of engine frame work of rolled steel. The construction of seatings, A-frames, liner casings with water, air and exhaust gas spaces formed of steel sections and plates electrically welded together, has already been satisfactorily tested on auxiliary sets of small engines.

This is proposed for large installations, and designs of a Doxford engine of this construction have been published.

The more modern designs aim at reducing the space occupied by the engines and the weight per horse-power.

The *Motor Ship* for August, 1935, gives the following figures for the fuel consumption of these engines as compared with the consumption of engines built ten years ago.

The consumption for Sulzer and Burmeister & Wain engines is ·33 to ·335 lb. per B.H.P. per hour and for Doxford engines ·325 lb. per B.H.P. per hour, representing a reduction of 12 per cent. in consumption. The heat retrieved from the exhaust gases is stated to represent a saving of 3 to 6 per cent.

Some vessels which have been fitted with this form of propelling machinery are given in chronological order in the following list, to illustrate the development of the Diesel engine.

One of the first large installations was that of the "Aorangi," of 17,491 tons gross, built in 1924, having four screws driven by four six-cylinder engines of the Sulzer 2 S.C.S.A. type. The cylinders were 700 mm. diameter, with a stroke of 1,000 mm. The brake horse-power was 13,000 at 127 revolutions per minute, scavenging by turbo-blowers was a feature of this vessel's installation.

The "Monte Sarmiento," 13,625 tons gross, built the same year, is driven by 4 S.C.S.A. engines of the M.A.N. type, having four sets of six cylinders 600 mm. diameter and 700 mm. stroke, coupled by single-reduction gearing to two screws. The brake horse-power is 14,000 at 77 revolutions of the propeller shafts and 215 revolutions of the engines' shafts.

In 1925 was built the "Gripsholm," of 17,914 tons gross, the first large Burmeister & Wain 4 S.C.D.A. installation. The vessel has two screws, each driven by six cylinders of 840mm. diameter and 1,500mm. stroke and independently driven air compressors. The brake horse-power at 130 revolutions is 14,000.

The same year the twin screw "Asturias," of 22,071 tons gross was built, driven by eight cylinders of 840 mm. diameter and 1,500 mm. stroke on each shaft. The air compressors were driven by the main engines. The brake horse-power was 14,500 at 115 revolutions per minute.

The "Heidelberg," of 6,350 tons, built in 1925, is a vessel propelled by a single screw, driven by two sets of M.A.N. 4 S.C.D.A. engines through single-reduction gearing and a Vulcan hydraulic transformer clutch. The cylinders are 640 mm. diameter and 700 mm. stroke and there are eight in each set. The engines' shafts rotated at 215 revolutions and the propeller shaft at 80 revolutions per minute. The brake horse-power is 4,100.

The "Accra" was built in 1926 and is 9,337 tons gross. This vessel has two sets of Harland & Wolff B. & W. 4 S.C.D.A. engines, each of six cylinders 680 mm. diameter and 1,400 mm. stroke, driving two propellers at 100 revolutions per minute, giving 5,600 B.H.P. The air compressors are driven by the main engines.

The Beardmore-Tosi engine liner "Itape" was built in 1927, being 4,978 tons gross. The two screws are driven each by six-cylinder engines 4 S.C.S.A. 650 mm. diameter and 1,100 mm. stroke. These engines are supercharged and on trial had a brake horse-power of 4,072 at 140 revolutions per minute, with air pressure of 25 ins. of water.

The "Bermuda," a quadruple-screw vessel of 19,086 tons gross, built in 1927, had four-cylinder engines of the Doxford opposed piston 2 S.C.S.A. type. The cylinders were 600 mm. diameter with strokes of 1,040 mm. and 760 mm. The brake horse-power was 13,500 at 125 revolutions per minute.

The vessel was burned out twice but the engines sustained very minor damage in consequence. The motor room on each occasion was flooded and the machinery on removal from the ship was practically unharmed.

Another vessel of the year 1927 was the Italian liner "AUGUSTUS," of 30,418 tons gross, propelled by four screws with M.A.N. 2 S.C.D.A. engines. The 24 cylinders are 700 mm. diameter and 1,200 mm. stroke and the brake horse-power is 28,000 at 125 revolutions per minute.

The "RANGITIKI," built in 1929, of 16,698 tons gross, is a twin-screw vessel, having Sulzer 2 S.C.S.A. type engines. The ten cylinders are 900 mm. diameter and 1,600 mm. stroke. This is apparently the largest diameter cylinder fitted to any vessel.

There was built in 1929 the "ULSTER MONARCH," of 3,757 tons gross, having twin screws, each driven by ten 4 S.C.S.A. trunk-piston cylinders 630 mm. diameter and 980 mm. stroke. Solid injection of the fuel is adopted and a waste-heat boiler heated by the exhaust gases—or oil burners on a gravity system—give steam at 80 lb. per sq. in.

The "BRITANNIC," of 26,943 tons gross, was built in 1930 and has twin screws. The engines are 4 S.C.D.A., having twenty cylinders 840 mm. diameter and 1,600 mm. stroke. A brake horse-power of 20,000 at 102 revolutions is developed. The fuel is injected by blast air supplied by four independent oil-engine-driven compressors. Steam is supplied at 100 lb. per sq. in. by six boilers heated by the exhaust gases, and by two cylindrical multitubular boilers at 120 lb. per sq. in., which are oil fired. (Fig. II.)

The "AMERIKA," of 10,110 tons gross, built in 1930, was fitted with Burmeister & Wain 2 S.C.D.A. engines, having a single screw driven by six cylinders 620 mm. diameter and 1,400 mm. stroke. 7,000 brake horse-power is developed at 95 revolutions per minute. The exhaust valves in this design are driven by a separate crank shaft, connected to the main shaft by a chain drive.

In 1931 the "REINA DEL PACIFICO," of 17,707 tons gross, was built and had four screws. The engines are of the 4 S.C.S.A. trunk piston type, and there are 48 cylinders 630 mm. diameter and 1,200 mm. stroke. Solid injection of the fuel is used. The exhaust gases drive turbine air blowers for supercharging, and are also passed through waste-heat boilers, giving steam at 100 lb. per sq in. The shaft horse-power is 22,000 at 145 revolutions per minute. (Fig. III.)

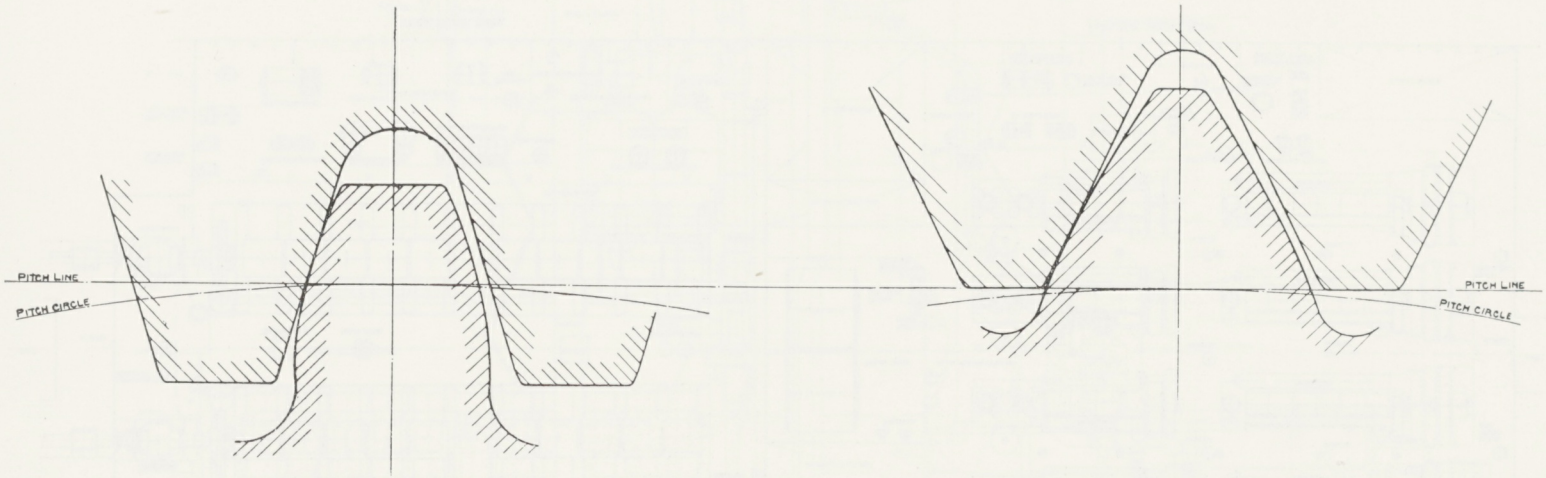
The "NEPTUNIA," of 19,475 tons gross, was built in 1932 and, propelled by four screws, has Sulzer 2 S.C.S.A. engines and 34 cylinders 680 mm. diameter and 1,000 mm. stroke. The engines develop 18,000 brake horse-power at 130 revolutions per minute.

In 1933 the "MALAITA," of 3,310 tons gross, was built and was the first passenger liner to be fitted with Burmeister & Wain two-stroke-cycle S.A. engines. This is a single-screw vessel, having eight cylinders 500 mm. diameter and 900 mm. stroke. The brake horse-power is 1,740 at 110 revolutions per minute. The exhaust valves are connected to the main crank shaft by eccentrics.

The "DURHAM," of 10,893 tons gross, was built in 1934 and has twin screws. The 16 cylinders are 720 mm. diameter and 1,250 mm. stroke, and are 2 S.C.S.A. Sulzer type. The brake horse-power is 11,000 at 125 revolutions per minute. The telegraph control from the bridge prevents the engines being rotated in the opposite direction to that indicated from the bridge. This vessel is supplied with steam from two waste-heat boilers at 120 lb. per sq. in., heated by the exhaust gases.

The "STIRLING CASTLE," of over 25,000 tons gross, is fitted with twin screws, driven by Harland & Wolff Burmeister & Wain 2 S.C.D.A. engines. There are 20 cylinders 660 mm. diameter and 1,500 mm. stroke. The scavenge air is supplied from separate units, which are electrically driven. There are four of these units. The exhaust gases generate steam in two waste-heat boilers at 100 lb. per sq. in. A vibration damper is fitted at the forward end of each crankshaft, which has the duty of minimising the effect of strains which might be developed in the event of the engines passing through a critical period of torsional vibrations.

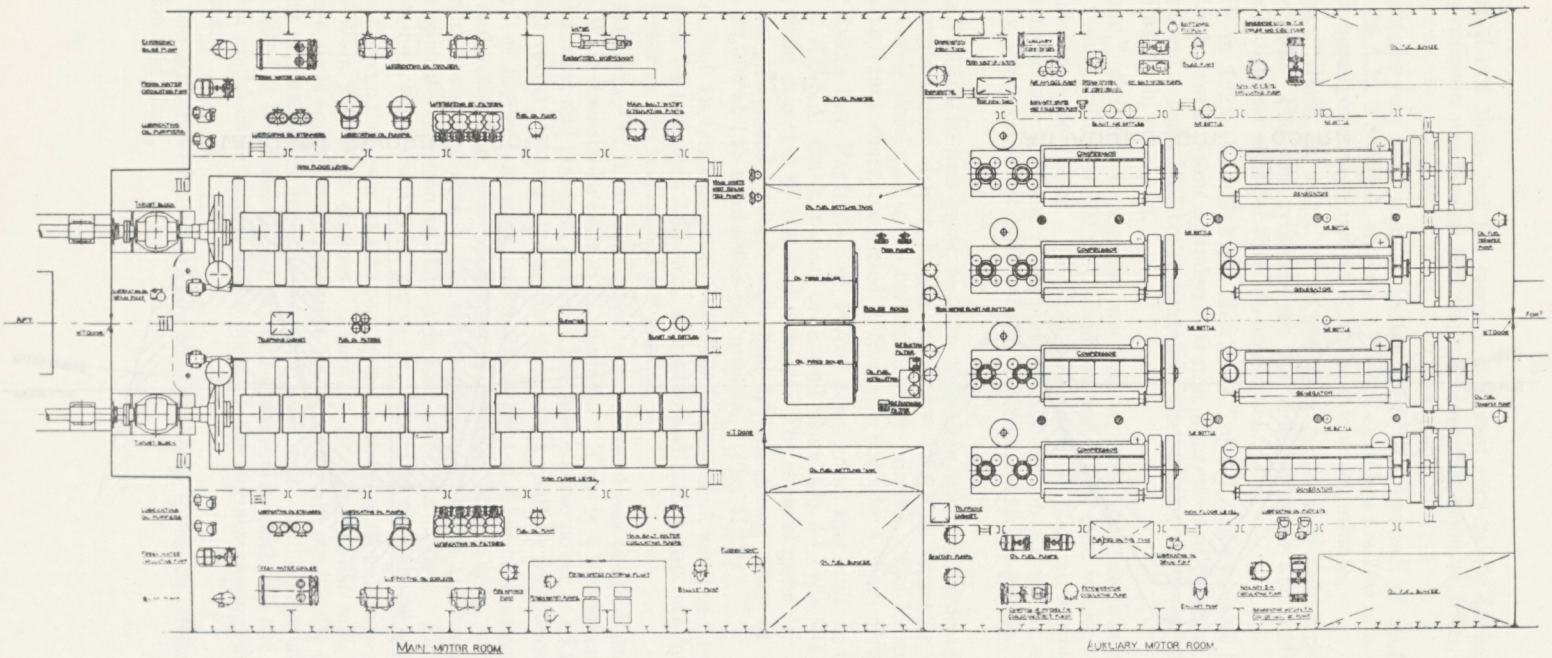
In conclusion, the author wishes to acknowledge the help given by Messrs. Harland & Wolff, in supplying information and plans.



Standard Involute Tooth.

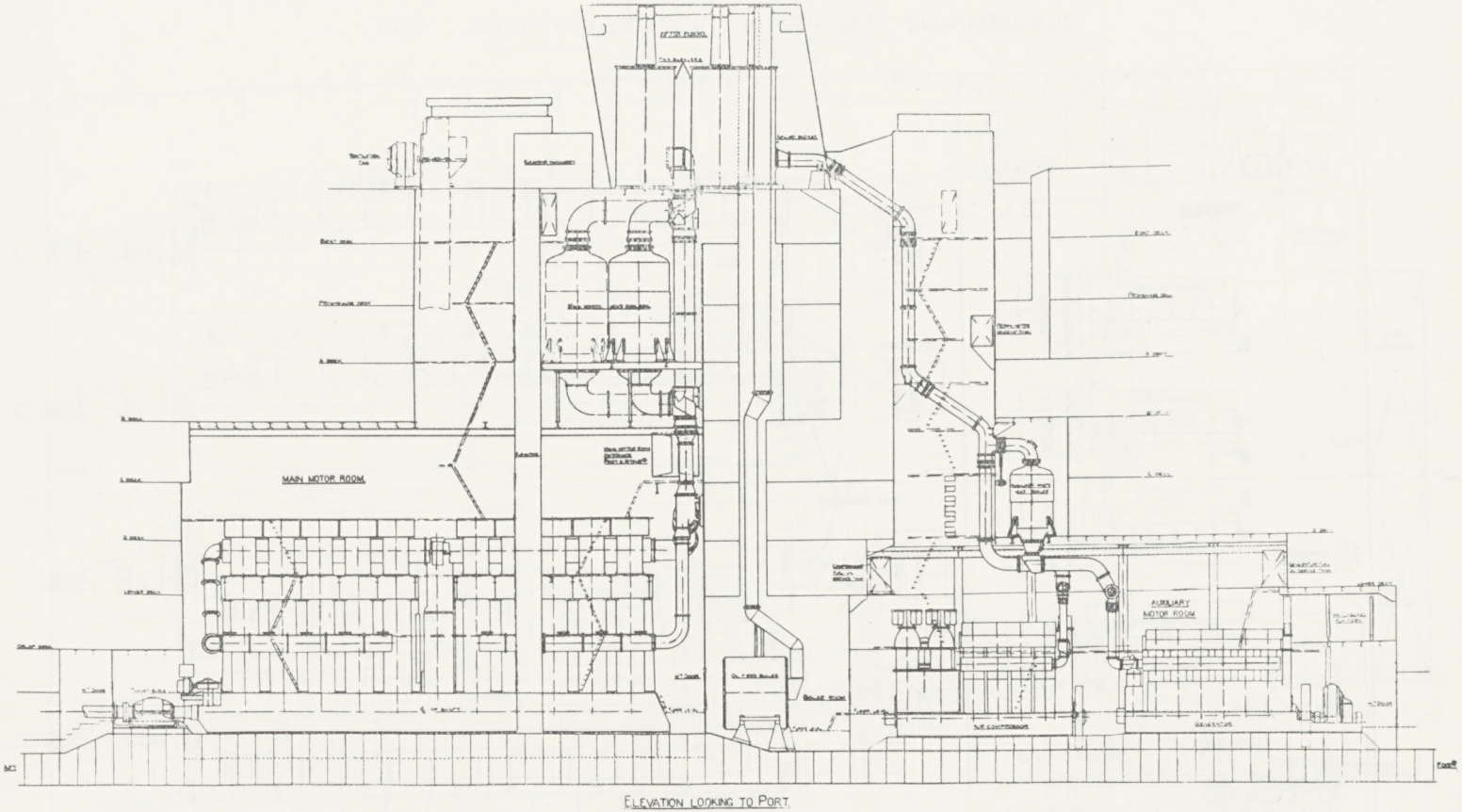
"All Addendum" Tooth.

Fig. I.



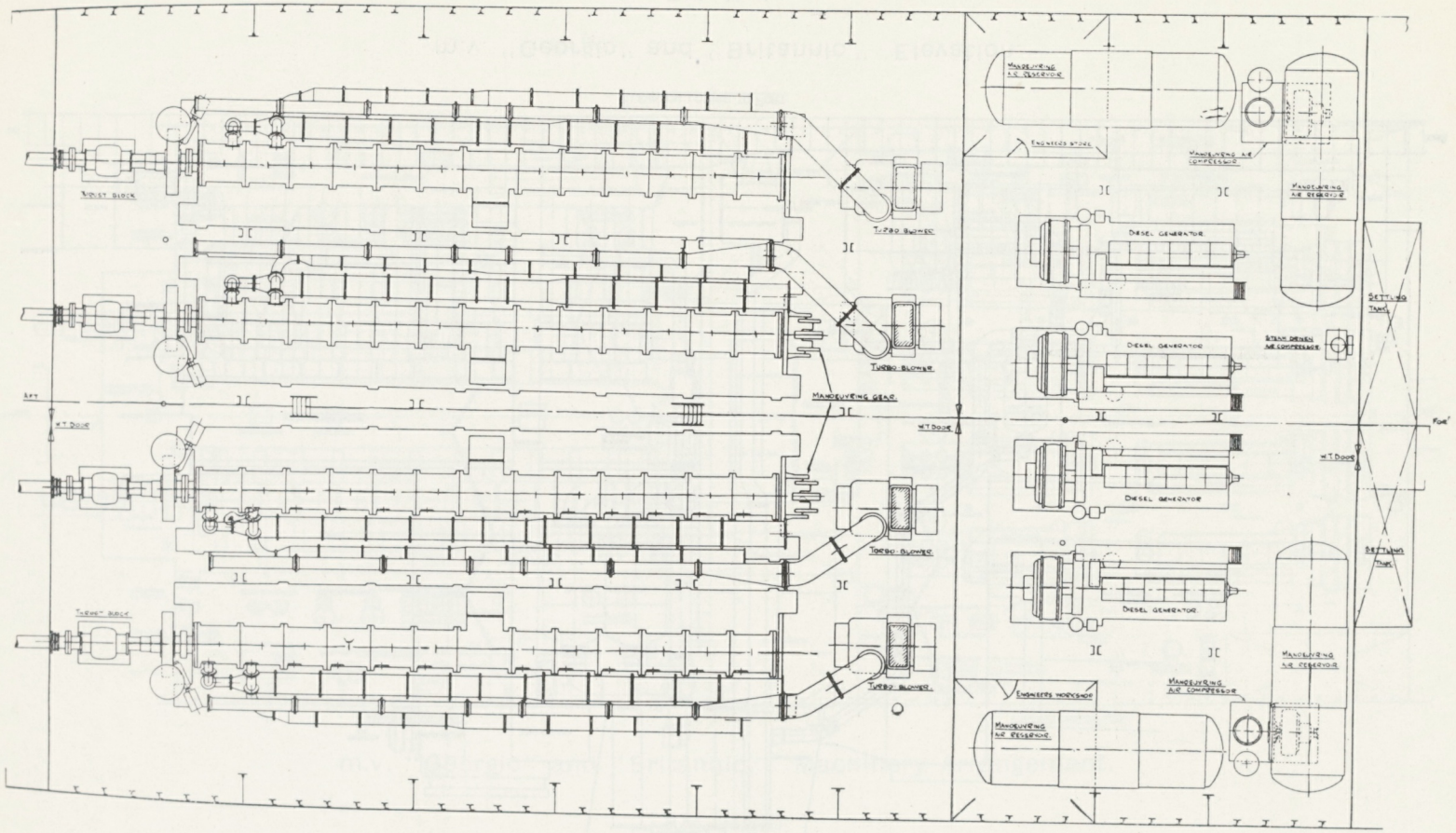
m.v. "Georgic" and "Britannic." Machinery Arrangement.

Fig. II (a).



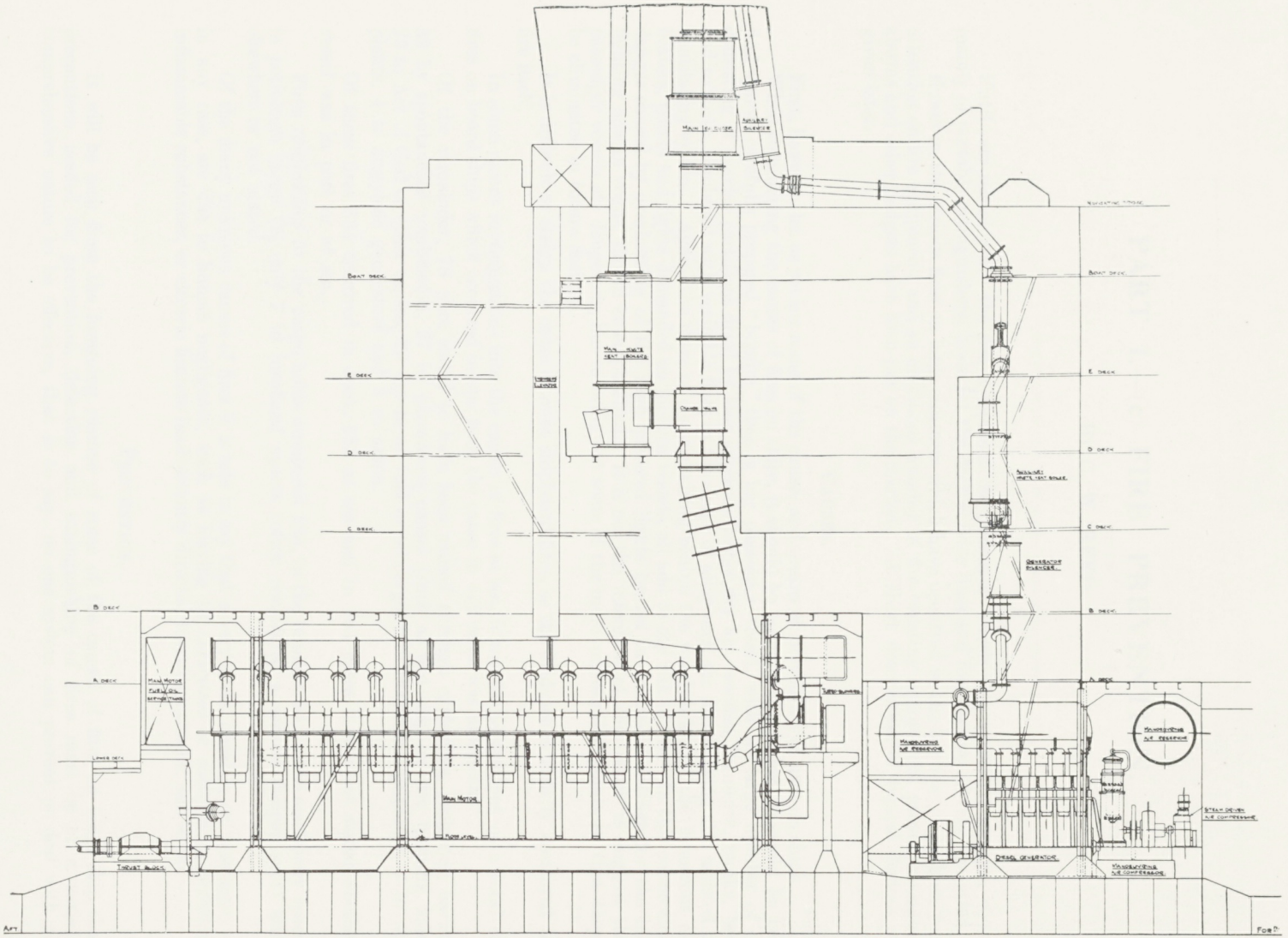
m.v. "Georgic" and "Britannic." Elevation.

Fig. II (b).



m.v. "Reina del Pacifico." Machinery Arrangement.

Fig. III (a).



ELEVATION LOOKING TO PORT.

m.v. "Reina del Pacifico." Elevation.

Fig. III (b).

PART I.—(c) FIRE PREVENTION.

By C. W. REED.

Until very recent years the fire equipment on passenger vessels was somewhat meagre, consisting mainly of portable extinguishers, hoses for the deck service lines and foam where oil fuel was fitted.

However, the serious fires on large steamers which have occurred in the last few years, have focussed attention on fire equipment, and an enormous number of fire-resisting compounds, paints, extinguishers, alarms and other gadgets have been put on the market. A short description of typical devices will be given later.

Causes.

First, however, let us review some of the causes and means of prevention of fires on ships.

When considering the causes of fires on ships, it should be borne in mind that it would be hard to find a more carefully prepared "bonfire" than a big passenger vessel, with its large number of cabins consisting of wooden partitions dried by long exposure to hot dry air, wooden furniture, bunks, bedding and so forth, combined with veritable flues in the shape of alleyways, the flames being also assisted by the ventilating system. Again, the maze of electric wiring behind the woodwork and the numerous electric heaters, points and lights demanded on modern vessels, all add to the risk of fire. In this connection, the danger caused by overheating of the high powered lights buried in concealed fittings for the indirect lighting now in vogue, should be emphasised. It is not the intention of this paper to suggest that all passenger vessels are dangerous, but to bring out some of the more undesirable points so that they may be eliminated in future designs.

It is difficult to assign the cause of most shipboard fires, as the evidence is usually destroyed by the fire itself.

In some recent investigations into the causes of fires at sea, it was found that out of a total of 688 fires on board ships which occurred in one year, the cause in 479 cases was unknown.

Of the remainder, 78 were stated to have been caused through explosions, including backfiring, 32 by spontaneous combustion, 27 by extraneous causes (such as one ship on fire igniting another), 23 to Act of God or other causes, 28 due to oil fuel or oil cargo, 8 to electrical equipment, 6 to welding plants, 4 to acetylene generators and 3 to arson.

Of these fires 334 occurred in dock, 253 at sea and in 101 cases it was not stated whether the vessel was in port or at sea.

Fires originating in the cargo holds numbered 136, in the bunkers 96, in the machinery spaces 73, in petroleum cargo 16, only 7 in insulated spaces (often considered a serious danger spot) and 360 elsewhere or not stated.

Of the many unknown causes of fires it is safe to say that a very great number, on passenger vessels in any case, are due to human negligence, such as leaving lit cigarettes or matches in proximity to inflammable substances, or electric heaters inadvertently directed towards curtains, and so on.

Prevention.

It will be seen from the foregoing résumé of some of the causes of fires on board ship that the precautions needed for prevention, detection and extinguishing of fires must be of a varied and comprehensive nature to be effective, that is to say, no one system can prevent or deal with all the

various fires likely to occur. For passenger vessels it is considered that by far the best is the human patrol. To be effective, the patrol should be thoroughly trained in fire detection and fighting methods, be very frequent and cover the whole ship.

This may be costly, but if well done is a good form of insurance and superior to any automatic alarm or detector.

Other obvious precautions should be insisted on, such as electric supply to empty cabins or cargo spaces being cut off at the mains, fine mesh gauze fitted over ventilators which may be convenient for depositing cigarette ends, spark arresters fitted to galley funnels and so on.

Other preventative measures suggested are the abolition or reduction of the amount of inflammable materials used for constructional, decorative or furnishing purposes. New designs should be considered with regard to arrangement of cabins, alleyways, stairways and lift shafts in order to obviate through air currents. Fireproof doors should be fitted in alleyways, especially near stairways and cross alleys. Main fireproof bulkheads should be carried the full height of the vessel and not stopped at the various decks. Consideration might be given to the fitting of "fireproof cofferdams," consisting essentially of two steel bulkheads about two feet apart, extending the width and height of the ship, and constituting a cofferdam which may be flooded by means of sea valves and pumps in case of emergency, and so isolate the fire to one half of the vessel. It is considered that this cofferdam might take some considerable time to fill and would constitute difficulty in access in accommodation. It has been fitted to at least one French liner, however.

There are many processes now on the market for rendering timber and paintwork non-inflammable, and a short description of some tested methods might prove interesting.

There are several processes on the market claiming to render timber fire resisting. Briefly, the treatment consists of submitting the wood in a closed cylinder to a steaming and vacuum treatment when the sap and moisture in the pores is vaporised, after which the wood is impregnated with a solution, under pressure, of antipyrine chemicals which, on drying, leaves the chemicals in minute crystalline form embedded in the fibres of the wood. When heat is applied the crystals expand and form a glassy coating which prevents the oxygen in the air combining with the wood. In consequence no spread of fire through the treated wood can take place and the wood merely chars. It is stated that wood treated in this manner is used in the "QUEEN MARY" and the Royal Navy, etc.

Another method of treating timber is by applying fireproof paint. The names of these so-called fireproof paints are legion, and tests on many of these have been witnessed by the author on behalf of the Committee of Lloyd's Register of Shipping. The results obtained on some are extraordinary, and on others disappointing, to say the least.

Several experiments were witnessed, the first, more spectacular than convincing, consisting of two or more open packing cases placed on their sides on bricks. One of these cases was painted with the fire-resisting paint, and one left untreated. Equal quantities of shavings soaked in petrol were placed inside and ignited. The untreated case, of course, was entirely consumed, whilst the treated case was found to be intact after the inside fire had burnt out. In this box, numbers of large unbroken blisters had formed inside. These blisters, which were of a metallic nature, were scraped off, and the wood underneath was found to be only very slightly charred, which would indicate that the timber had been protected to a remarkable degree. Further, and more astonishing experiments, consisted of painting a piece of timber on one side only with the paint, placing the timber vertically on a stand and applying the flame of a blow lamp to the painted surface. The blow lamp flame was stated to have a temperature of 2,500°-3,000° F. at a distance of 7 ins. from the nozzle. In this case, the flame was left playing on the painted timber for over half an hour. The lamp was then removed, the blistered paint scraped off, and the wood underneath found only slightly charred.

Woodwork coated with of these preparations may be given a finishing coat of ordinary oil paint or enamel. It is not claimed that the covering paint is rendered non-inflammable, but that the fire-resisting paint acts as a barrier between the flames and the wood.

Photographs taken by the author at a demonstration of one of these paints are shown (Figs. 1 and 2). The treated box is seen to be intact, whilst the untreated one is burnt away. The blow lamp playing on another sample is visible on the bench in the background.

Other fire resisting materials include asbestos in the form of clothes, boards, etc., and also various protected plywoods which may consist of a plywood enclosed within galvanised sheeting; it is claimed that while the wood may char, burning cannot take place; aluminium may be used instead of galvanised steel. Other variants are plywood which has been subjected to a fire-resisting process, or plywood glued under hydraulic pressure to asbestos slate.

A point to be noted in connexion with the use of this type of material for structural work is that the strength of the material in some cases is practically destroyed, so that collapse may take place.

Stowage of cargo is important in respect to prevention of fires, but it is not considered to be of interest to members of the Association.

The Board of Trade issue a booklet dealing with the carriage of dangerous goods, but other goods, such as fibrous substances (wool, flax, tow, copra, etc.), should not be stowed with oils or fats, etc., owing to the liability of the former substances to spontaneous combustion.

Detecting and Extinguishing Apparatus.

It is thought well to deal jointly with apparatus for detection and extinction of fires, as often the piping and gear fulfil both functions.

Once again the human patrol is emphasised as the best means for both purposes, provided it is a frequent and efficient patrol, and not merely one ancient night watchman dozing in the galley, as is so often the case, especially in port.

The patrol will, of course, know the positions and uses of the hoses on the deck lines, stop valves, portable extinguishers, alarms, smoke helmets and so on, thus being able to bring into action as soon as possible the correct article required.

As, however, a patrol cannot be in every part of the ship at all times, his usefulness will be greatly supplemented by the fitting of automatic alarms, detectors and extinguishers. These are generally of two kinds, those suitable for passenger accommodation and those for inaccessible spaces, such as cargo holds, stores and so on.

A brief description of the principles underlying the better known types will now be given, and it can then be left to the Surveyor to recommend whichever type he considers most suitable for the particular part of the vessel concerned.

A system for use in stores, cargo holds and other inaccessible spaces, gives warning of a fire in these spaces by sight and smell.

It consists, shortly, of a system of pipes led from each space to a cabinet on the bridge. A fan draws air samples continuously from these spaces in turn through the cabinet, where a light beam makes any slight trace of smoke visible and indicates the hold from which the smoke is drawn. After passing the cabinet the air is exhausted into the wheelhouse, giving a further fire indication by smell.

To ensure reliability the fans are in duplicate and are fitted with an automatic "trouble" signal.

A system usually combined with the system described above, consists of a battery of carbon dioxide cylinders manifolded together, and connected by means of a quick discharge non-freezing valve into the pipes to each hold through which the air samples are drawn, thus discharging CO_2 gas into the hold which shows the smoke.

A modern improvement on these systems, is a combination of the standard system for visual detection of smoke with a photo-electrically controlled arrangement for the audible detection of smoke. Naturally, the photo-electric cell is much more sensitive than the eye, and detects smoke in quantities so minute as would otherwise escape notice.

This audible detector consits of a light beam, which is projected through a long tube on to a cell of the self-generating type. When the air in the tube is clear, the full amount of light reaches the cell and its output is normal. When, however, smoke is present in the tubes, the amount of light reaching the cell is reduced, which in turn decreases the output of the cell, permitting a relay to close

which operates a fire alarm, shows a red light and indicates the number of the affected hold in the cabinet. The alarm gong can be switched off, but the red light shows as long as smoke comes from the affected hold. Visual detection continues meanwhile without interruption in the other holds. This system appears to be especially useful in port where a continuous watch on the cabinet may not be kept. If anything goes wrong with the exhaust fans, the visual or audio lights, the alarm gongs or the voltage control, then a buzzer will sound and a "trouble" lamp light.

The detector is equipped also with a voltage regulator, that automatically compensates for voltage variations in the mains, preventing false alarms due to variations in the intensity of the light source. A diagrammatic arrangement is shown in Fig. 3.

A further system of fire detection is intended for passenger accommodation, whereas the systems previously described are intended for unattended closed spaces such as holds, baggage rooms and stores. It consists of a number of electrical circuits connected to thermostats located in cabins and crew's quarters, and manual alarm stations in passage ways. These circuits terminate in the wheelhouse in a cabinet which contains alarm gongs and a panel that indicates the location of the fire.

When a fire breaks out in a cabin, the operation of the thermostat in that cabin rings the gong and shows the officer on watch the exact designation of the cabin fire. With this system, up to about 50 thermostats may be connected to one circuit. The thermostat is mounted flush on the ceiling with the wiring concealed, and is basically a switch held open by a Grinnell quartz bulb such as is used with sprinklers. This bulb shatters when heated to its rated temperature (135° F. or 175° F. or higher as desired) and allows the contacts to close the circuit and sound the alarm. The contacts are hermetically sealed in a bakelite cup behind a monel metal spring disc, eliminating danger from corrosion. The quartz bulb contains a special non-freezing liquid and a bubble of air. When the bulb heats up the liquid expands and compresses the air until at the rating temperature it compresses the air to a liquid and shatters the bulb.

The above-mentioned quartz bulb is the same that is used in some "sprinkler" systems.

This sprinkler system has been in use in land warehouses and shops for many years, but has now been adopted for marine work, and is fitted in the "STRATHMORE" and "QUEEN MARY" amongst other large liners.

The protected ship is provided with a system of piping carrying water under pressure to a number sprinkler heads fixed to ceilings of cabins and saloons, placed so that every corner of the room is within range of the water spray from the head. This sprinkler element or head is shown in section in Fig. 4. A glass ball valve is seated upon a flexible metal diaphragm, and is held in position by a quartz bulb fitted into end pieces. When fire causes the temperature to rise beyond a predetermined figure, the bulb shatters and allows the valve to drop, and the water to escape, impinging upon a deflector, which forms a drenching spray over a wide area.

A variable pressure alarm is incorporated with the pipe system and is operated by the flow of water, and sounds an alarm on the navigating bridge, where visual warning is also given on a panel, which indicates which sprinkler is in action.

There are, of course, many other types of alarms and detectors made by various firms, more or less similar in action to one or other of the above, if somewhat different in construction, but as this paper is not intended to be a catalogue, we will now pass on to a somewhat different type of extinguishing apparatus, intended for fires in oil fuel.

When it is particularly designed to deal with fires of inflammable liquids, the principle of operation is to convert, using water, a sufficient depth of the liquid from the exposed burning surface into an emulsion, which is itself incapable of burning.

Water is forced out of specially designed sprayers on to the surface of the burning liquid, in the form of fine jets, in such a way that the whole of the surface of the oil is broken up into a number of extremely small globules, each of which is effectively surrounded by a film of water, and the emulsion thus formed excludes the possibility of continued combustion.

Chemical Extinguishers.

Portable extinguishers of the type seen in every building are extremely useful, distributed about a ship for dealing with small local fires.

The main types are as follows:—

Soda-Acid type, for general use.

Methyl-Bromide type, for general use.

C.T.C. (Carbon Tetra Chloride) type for small oil fires or fires in electric equipment.

Foam, or Froth, type, for fires in boiler rooms, etc.

Modifications in design found necessary and precautions to be taken with modern electrical installations on passenger vessels, such as possible overheating due to concealed lighting, is left to be dealt with in the joint paper on electrical equipment.

Mention may be made, before concluding, of the advisability of providing masks or clothing for use in dealing with fires.

Asbestos clothing is now made so that a man can walk into a fire unscathed, but it is considered that complete suits are rather cumbersome and hardly necessary.

Asbestos gloves and boots which can be quickly pulled on save many burns, and smoke helmets or, better still, oxygen breathing apparatus, should be supplied so that men can penetrate smoke filled alleyways

Some smoke helmets are supplied with air by means of a long hose leading from the man to a pump, but the hose is unwieldy and the pump may even come within the smoke area and pump smoke instead of air.

Oxygen breathing apparatus consists of a self-contained gas mask connected to a cylinder carried slung on the body, containing oxygen sufficient for half an hour or longer, and a CO_2 absorbent cartridge, thus the wearer is unencumbered with long trailing hoses limiting his radius of action.

He can enter an atmosphere of 100 per cent gas and can breathe quite freely, even lying flat or crawling on hands and knees.

It is necessary that some of the crew be trained in the use of these apparata, otherwise valuable time, and perhaps lives, would be wasted if untrained persons attempted to use them.

This brings us back to the point, already reiterated, that the main and surest safeguard against fires on ships is an efficient patrol and a number of persons well trained in the various anti-fire appliances on board.

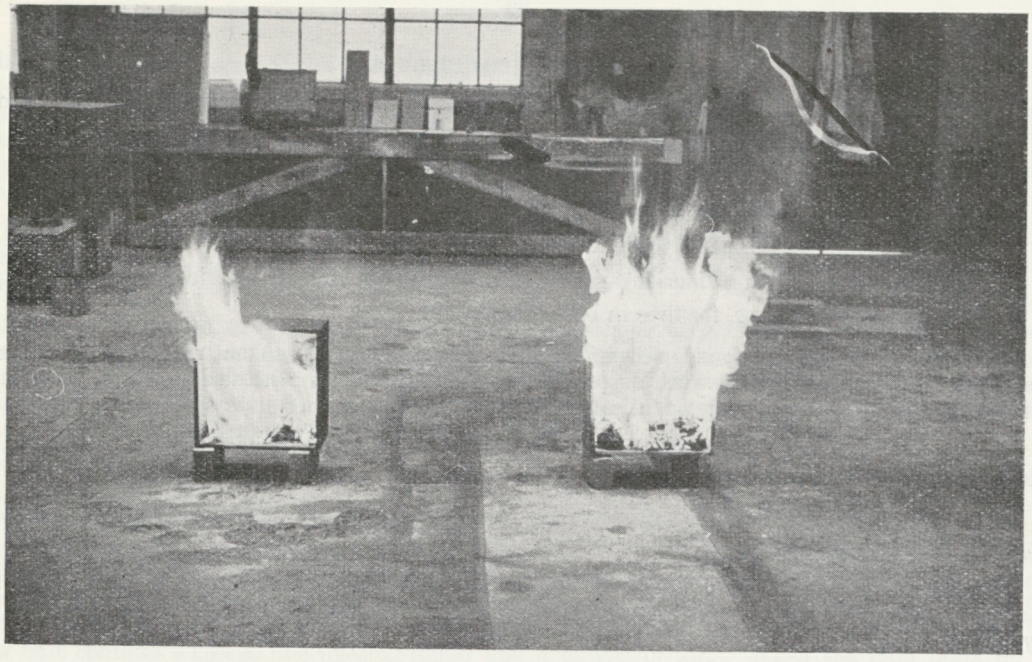


Fig. 1.

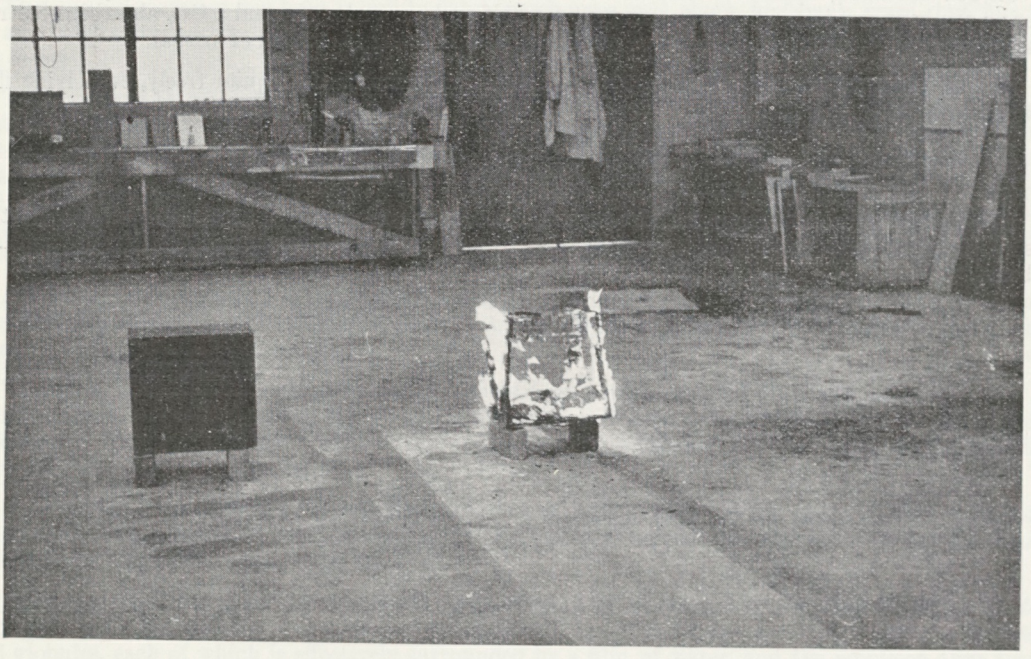


Fig. 2.

SCHEMATIC DIAGRAM SHOWING PATH OF SMOKE THROUGH DETECTOR.

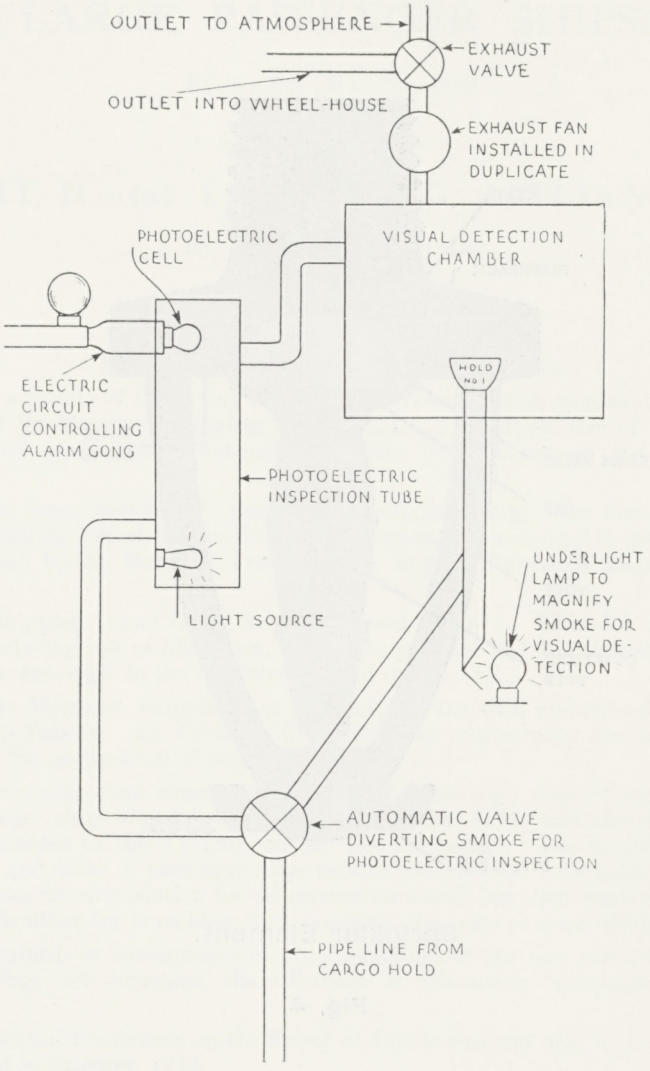
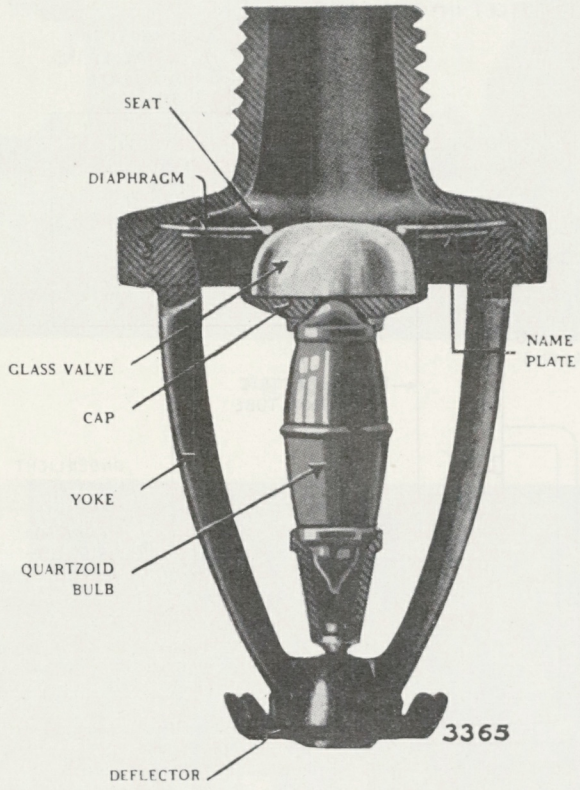


Fig. 3.



Sprinkler Element.

Fig. 4.

NOTES ON RECENT DEVELOPMENTS IN LARGE PASSENGER SHIPS.

READ 5TH MARCH, 1936.

PART II.—(a) LIFE-SAVING APPLIANCES.

BY E. W. BLOCKSIDGE.

HISTORICAL STEPS IN THE DEVELOPMENT.

The provision of a system of life-saving equipment on board British merchant ships was inaugurated by the introduction of the Merchant Shipping Act in 1854. The largest size of ship provided for was 1,000 tons (Registered tons), the complement of boats being based on the register net tonnage at that time.

During the seven years previous to this Act 61 emigrant ships were lost at sea. In the twelve years following an appalling loss of life occurred, and the casualties continued to increase, notwithstanding the regulations imposed by the Board of Trade and the improved methods adopted in the construction of ships.

The Merchant Shipping (Load Line) Act was passed in 1875. This did not appear to have an immediate effect on reducing loss of life at sea, for, in the year 1877, 2,650 British seamen were lost, and again in 1882 the loss was equal to the excessive ratio of one in 75.

Then in 1894 the Merchant Shipping Act of 1854 was amended and extended in its application of rules for life-saving appliances. An Advisory Committee, as representing the shipping interests, was appointed to assist in the preparation of regulations.

For some years following these enactments, casualties at sea were reduced considerably, and the loss of life on large passenger ships engaged in the North Atlantic trade was almost negligible, until the regretable disaster occurred to the TITANIC on her maiden voyage. The result was the introduction of further legislation, and decks of passenger ships became overcrowded with boats stacked in tiers, in an endeavour to obtain boat accommodation for all persons on board, but their ready availability in a sudden emergency, with the facilities for launching then available, was open to grave doubt.

The experience gained, in consequence of the application of the new rules, appeared to prove that the new legislation had not increased the efficiency of life-saving equipment to the extent that was anticipated.

The first International Conference on the Safety of Life at Sea was held in London in 1913, and the Convention was signed in January, 1914.

New rules for life-saving appliances were issued by the Board of Trade in 1913 and 1914.

In 1921 and 1923 papers were read before the members of the Institution of Naval Architects, and the Institute of Marine Engineers, at the Shipping and Engineering Exhibition in Olympia, with a strong appeal for an improved standard of life-saving equipment for passenger and cargo ships, based on the experience gained since the International Convention of 1914, particularly during the period of the Great War.

An outline of the main proposals then made are now enumerated, as giving an indication of the developments on modern large passenger ships of life-saving equipment, and it will be seen from the further consideration of the subject in this paper, how far they have been embodied in subsequent legislation.

(*a*) Only such lifeboats to be carried on passenger ships as can be attached to, or stowed immediately under davits *at the ship's sides.*

(*b*) The provision of buoyant apparatus, 25 per cent in excess of the full accommodation in boats.

(*c*) A complete revision of the various classes of lifeboats.

(*d*) All lifeboats to be fitted with efficient hand pumps and provided with towing arrangements.

(*e*) The extended use of motor lifeboats on passenger vessels of 10,000 tons gross tonnage and above to act as convoy leaders, and fitted with wireless telegraphy.

(*f*) The compulsory provision of emergency lighting apparatus, and the equipment of wireless direction finders.

(*g*) The provision of rope ladders stowed and secured at the ship's sides.

(*h*) Bilge or life rails and equipment lockers to be fitted on all boats.

(*i*) Masts and sails to be abolished, except in the emergency boats. A light pole mast for signalling provided in lieu.

The second and last International Convention for the safety of life at sea was signed in London in June, 1929, followed by the Merchant Shipping (Safety and Load Line Convention) Act of 1932.

Transit By Sea is the Safest.

Finality may now appear to the travelling public to be almost an accomplished fact, in the effort to provide an efficient arrangement of life saving appliances on board passenger ships as the second line of defence against casualty at sea, but to the naval expert there still remain several avenues in which research could be made with advantage.

The ship, constructed under supervision to a standard of strength, with its watertight compartments, fire-fighting and radio-telegraphy equipment, is the first and most important line of defence against casualty.

One of the greatest factors which have influenced the solution of the problem of saving life at sea is radio-telegraphy, the wireless direction finder which is a statutory requirement for all ships of 5,000 tons gross and above, and subsidiary agents such as submarine telephony and echo depth-sounding apparatus.

The second line of defence against casualty, with which this portion of the paper deals in detail, includes the provision of a number of lifeboats accommodating the total complement of passengers shown on the passenger and safety certificate, and the crew, which can be effectively launched without hindrance in a reasonable measure of time.

The time factor will always remain one of debate, but it is reasonable to suggest that the equipment should be such as to permit of the whole of the passengers and crew being embarked and the boats launched from the ship within 30 minutes of the casualty.

The third and last line of defence relates to buoyant apparatus which did not form a part of the statutory regulations until July, 1925, and the equipment of a number of lifebuoys, and a life-jacket for every person on board.

The development of life-saving appliances for passenger ships has been brought gradually to its high standard of efficiency by the Board of Trade, with the practical co-operation of British Shipowners and all the interests of the Merchant Service. The result has been to make the passenger ship the safest means of transit.

In Fig. 1. will be found a diagram giving the number of persons, including passengers and crews, for both cargo and passenger ships, lost at sea over a period of years from 1900 to 1934. Three years stand out prominently, when the three passenger ships Camorta, Titanic and Empress of Ireland were lost. The average number of persons lost per year over a period of 28 years was 378, and the average over the last 10 years was 113 persons. During 1935 over 6,000 persons were killed on the roads in this country and over 200,000 injured. The comparison is startling.

Ready Availability of Lifeboats.

It was not long after the signing of the first International Convention at London in 1914, that the fulfilment of the demand for a seat in a lifeboat for every person on board, or what was popularly referred to as "boats for all," became a positive danger rather than an improvement on the means provided for saving life on pre-Convention ships.

The decks of passenger ships became over-crowded with apparatus, and the mass of boats stowed inboard interfered seriously with the effective launching of boats stowed under davits at the ship's sides.

The effect of the new regulations following the first Convention was fully realised in subsequent disasters to ships when the emergency was sudden—as most casualties are at sea. Even under the most favourable conditions of weather the available boat accommodation could not be utilised, owing to the time taken with the transport of the inboard or second tier of lifeboats, and their interference with the speedy launching of the boats directly under and attached to davits at the ship's sides.

Thus it was seen that the rules which were promulgated to prevent such a disaster as occurred to the Titanic in 1912 were actually responsible for complicating the controlling gear for operating the life-saving equipment, prevented the lifeboats under davits being launched in the time available, and defeated the object for which the apparatus was placed on board. Consequently, in the International Convention in 1929, we find that the "time factor" is seriously considered, and the principle of the *ready availability of all boats* was included in the new regulations.

Emphasis was placed on the necessity for utilising the full available length of the ship by accommodating boats directly under and attached to davits at the ship's sides. If other lifeboats must be carried in addition to those under davits, they may be stowed across a deck, bridge or poop, and so secured that they will have the best chance of floating free from the ship if there is no opportunity to launch them overboard. They must not, however, impede in any way the prompt handling of the boats under davits, or the buoyant apparatus, or the marshalling of the persons on board at their embarkation stations.

It is along these lines that development is seen in the equipment of modern large passenger ships, and this development is indirectly responsible for the necessity of increasing the size of lifeboats.

The arrangement of concentrating all the available life-saving apparatus at the ship's sides is an advantage to the scheme of marshalling the passengers at definite positions where the work of transport is under better control of the ship's officers.

Launching Appliances.

A minimum number of sets of davits corresponding to the registered length of the ship is laid down in the rules of the Board of Trade, but no ship is required to have a number of sets of davits greater than the number of lifeboats required to accommodate the total number of persons which the ship carries or is certified to carry, whichever number is the greater.

In this connection provision is made in the regulations, in the case of a passenger ship where it is not practical or reasonable to fit the statutory number of davits, for the Board of Trade to approve of one or more sets of davits being dispensed with, subject to certain conditions which may be imposed.

As ships increase in size the launching or embarkation platforms rise to a greater height from the load water line, lifeboats are larger and, consequently, the mind of the designer has been concentrated on the efficiency of the launching apparatus.

The ideal arrangement must be one which is positive in its action, without the necessity of lifting the boat out of its stowing chocks, or swinging it into position, speedy in its action, with single wire falls which should be unkinkable and rust-free, and such that it is not necessary to fit special mechanism to move the launching apparatus against a heavy list by the ship.

The introduction of the gravity davit has increased greatly the efficiency of the boat lowering apparatus, and embodies all the foregoing requirements, thus avoiding the dangers associated with the ordinary radial davits. It is automatic and positive in its movements, and in conjunction with efficient electrical winches can launch the lifeboats against a list up to 30° with a minimum number of crew.

Large modern passenger ships are, therefore, equipped with gravity davits.

The QUEEN MARY has been installed with "Taylor" patent gravity davits. A photograph of this type of apparatus is shown in Figs. 3 and 4.

The French passenger steamer NORMANDIE was equipped with the Welan-Maclachlan Davits Ltd. patent gravity davits.

Associated with the launching apparatus must be an efficient gear for releasing the lifeboats from the falls at the moment the boat is required to take the water. It is obvious that means which provide for the simultaneous release of both falls of a large boat in a heavy seaway are preferable to independent release by hand, in fact the latter system may result in disaster. The Board of Trade do not demand that an automatic releasing apparatus should be fitted, but give particulars in the rules of the desirable features of such a gear.

A doubt may arise in the mind of the Owner or Naval Architect, as to the effect of this concentration of life saving equipment at the ship's sides on the number of passengers which the size of the passenger ship demands.

Investigations have been made regarding a number of passenger ships ranging from 500 to 1,000 ft. in length. *See* Fig. 2.

Curve A represents the average gross tonnage of passenger ships with suitable superstructures for the various lengths.

Curve B shows the total number of persons which can be accommodated in boats attached to the statutory number of davits at the ship's sides in single tier, having 100 persons in each boat. A modification is made to this curve, shown in dotted lines, for lifeboats accommodating 80 persons in each, for ships 750 ft. in length and below.

Curve C shows the number of persons per foot of length, referred to as the density factor, and which is based on Curve B for the average number of persons carried on large modern passenger ships. The average density is about 3·1 persons per foot of length of ship.

Curve D is a comparison of the density factor with Curve C. This is based on the number of persons carried on passenger ships round about the year 1922, and varies from 3·5 to 5·0 persons per foot of length of ship. In order to accommodate the total number of persons in lifeboats of the size constructed at that period and carried under davits at the ship's sides, it was necessary to stow the boats in double tier.

It will be seen, therefore, that the total number of persons carried on modern passenger ships is smaller than the average number carried in 1922, due, for one reason, to the growth of luxury accommodation. The advent of the large lifeboat in association with this reduction in number of passengers allows an arrangement of lifeboats where each is attached to a davit at the ship's side and stowed in single tier.

The conditions applying on actual ships have been plotted so that surveyors can draw their own conclusions, e.g., one ship (not British) about 650 ft. in length has superstructures for passenger accommodation which brings her gross tonnage considerably in excess of Curve A, with a total number of persons in excess of Curve B, necessitating very large boats for that size of ship.

If more passengers are carried on a ship which exceed those in Curve B and they are accommodated in boats in single tier, then the size of the boats must be increased or an arrangement of boats in double tier provided.

A word of caution may here be inserted. There may be a tendency in the future to reduce the statutory number of davits and increase the size of the lifeboats, and thus run the risk of "carrying all your eggs in one basket," but the matter is being carefully watched in order to safeguard an excessive reduction in launching stations.

STOWAGE OF BOATS.

The statutory requirements for stowing the lifeboats are as follows :—

(*a*) Each set of davits must have a Class 1 lifeboat attached thereto.

If the accommodation provided in these lifeboats is not sufficient for the total number of persons the ship is certified to carry; then

(*b*) Additional lifeboats of Class 1 or Class 2 are stowed under the davits, not more than one additional boat to each set of davits.

If the accommodation then provided in all the lifeboats is not sufficient for the total number of persons the ship is certified to carry; then

(*c*) The remaining boats, or liferafts (under certain conditions) shall be carried inboard.

The additional boats referred to at (*b*) and (*c*) are carried on board subject to the requirements of the rules in regard to their ready availability under all conditions of emergency, to which reference has already been made.

When the statutory number of lifeboats carried is more than 13, one of such boats must be a motor boat, fitted with an approved wireless telegraphy installation and a searchlight. When the number of lifeboats is more than 19, two of such boats must be motor boats and equipped in the same manner.

Any other motor boats carried, and which form part of the statutory equipment, need not be fitted with the installation of wireless telegraphy or searchlights.

The emergency, or "accident" boats, are always of the Class 1 type, equipped with oars, etc., and stowed near the navigating bridge. A motor or other mechanical means of propulsion can be fitted to these boats, but the full complement of oars must be carried.

Construction of Lifeboats.

The Board of Trade, under the provisions of the Merchant Shipping Acts, issued in 1920 the first edition of "Instructions as to the Survey of Life Saving Appliances," which was intended mainly for the use of their surveyors in carrying out inspections of British ships, and foreign ships entering British ports.

A new edition of these Instructions was published in 1926, which has been amplified by Supplements Nos. 1 to 4, issued in 1928, 1930, 1932 and 1934, respectively, bringing them into line with modern experience and practice, and giving effect to the provisions of the International Convention for the Safety of Life at Sea, 1929.

At the time of writing this paper, a new edition embodying all the previous regulations is about to be issued by the Board of Trade. (Issued Feb. 1936.)

A complete specification is now available giving all the details associated with the construction of all classes of lifeboats up to 30 ft. in length, together with their lifting hooks and equipment.

The effect of these Instructions has been to produce lifeboats of a very high standard of construction which are capable of standing years of service, and effective for the purpose for which they are intended.

The development of the modern lifeboat is not only the resulting effect of the minimum requirements of the Board of Trade, but due in no small measure to the ingenuity of the designers and the urge of competition.

Although the Board's instructions give certain information which guides a builder in regard to the form and proportions of lifeboats, the designers have endeavoured to provide a large measure of reserve buoyancy by incorporating in their designs a large amount of flare at the forward and after ends so as to lift the boat in a seaway, and at the same time preserving long straight sides which facilitate the embarkation of passengers, give better protection to the boats and passengers during the process of lowering, provide better stowage for the buoyancy air cases and the details of equipment such as masts and oars, and give the maximum capacity for the seating accommodation. Some of the features referred to can be seen in the illustration of the lifeboat under davits ready for lowering. *See* Fig. 6.

It was generally considered that the provision of a bailer and bucket, in accordance with the Board of Trade's instructions, was totally inadequate for the purpose of clearing water from a boat quickly, and particularly when the boat is filled with passengers. The Rules now demand an efficient hand-pump to be fitted in motor boats, and in all boats certified to carry more than 85 persons.

Large Lifeboats and Motor Lifeboats.

When the number of lifeboats carried on a passenger ship is more than 13, one of such lifeboats must be a motor boat, fitted with an approved wireless telegraphy installation and searchlight. When the number of lifeboats exceeds 19, two of such lifeboats must be motor boats and equipped as before described. Any of the other lifeboats, except the accident boats, may be motor boats, but they need not be fitted with wireless telegraphy apparatus or searchlights.

Where wooden lifeboats are designed to be certified for more than 85 persons, they are carvel built with planking worked on the diagonal system and fitted in two thicknesses.

In lifeboats for more than 60 and not more than 85 persons the Board of Trade recommend the foregoing system of construction, but if the owner wishes to adopt the clincher system of construction, additional transverse and longitudinal stiffening is demanded.

Vertical fenders are fitted to boats intended to accommodate more than 85 persons, extending from the gunwale down to the bilge, in order to facilitate launching on the high side of a listed ship, and are to be of sufficient number to prevent damage to the boats when being lowered. If the fenders are of wood, cope-iron is fitted to the outside edges. Alternative arrangements, such as skates or rollers, temporarily screwed to the boat to facilitate launching, may be fitted if approval is first obtained from the Board of Trade.

The whole of the lifeboats of the French passenger steamer Normandie are fitted with the Schat patent skates.

There is no reference in the Board of Trade regulations to facilities being provided on the lifeboats for dealing with persons who are in the water. There are life-lines and bilge-rails fitted to the boat, but the tendency of a person hanging on to these is for his legs to drag under the bilge of the boat and he has the greatest difficulty in reaching the gunwale, particularly in a large lifeboat. The need for some provision in the Rules to deal with this problem is imperative.

Where large lifeboats are fitted with vertical fenders, bars could also be fitted between the fenders whereby a person in the water does have a chance to haul himself up to the gunwale by these steps. The value of buoyant apparatus as a means of saving life is considerably reduced if facilities are not provided in the lifeboats for rescuing persons from the water.

The details of construction of motor lifeboats comply with the requirements for Class 1 lifeboats, but additional air-cases are fitted to compensate for the weight of motor machinery occupying space which in an open lifeboat would be occupied by passengers or crew. Additional buoyancy is also required when boats are built of steel.

For passenger ships engaged on an International voyage, the minimum length of a motor boat is 26 ft.

The Board of Trade instructions are very complete in regard to details of construction. Provision is made for towing, and where the boat is certified for 100 or more persons two bilge pumps are fitted, one being an efficient hand pump. When less than 100 persons are carried one bilge pump is fitted, and if a hand pump is not fitted, suitable plugs with chains are provided so as to permit of each watertight compartment being drained.

Special emphasis is placed on the quality and suitability of the propelling machinery, which must be maintained in efficient condition under all conditions of service and weather.

The engine may be driven by heavy oil or paraffin, but not by petrol. Petrol in small quantity may be used for the purpose of starting. The fuel must be sufficient to propel the boat for 100 miles, and the speed is not less than 6 knots.

Each lifeboat which is deemed fit to carry 100 or more persons is fitted with a motor, and complies with the general requirements of the Board of Trade for motor boats forming a part of the statutory equipment of a passenger ship. Only the motor boats carried in the proportion to the total number of lifeboats laid down in the rules are required to be equipped with an installation of wireless telegraphy and a searchlight.

The purpose of the motor boats is to act as "mother boats" to the remaining lifeboats, assisting in the general work of recovering passengers and crew from the water or buoyant apparatus, and to keep the flotilla together in order that help may be received from passing ships as the result of a call for assistance

by wireless telegraphy. It was for this reason that the writer, in his papers of 1921 and 1923, suggested the abolition of sails and the substitution of a pole mast for signalling, but the suggestion has not been adopted, for the reason, probably, that all passenger ships are not engaged on a busy trade route. In the case of a ship which carries passengers in the North Atlantic on a voyage not proceeding south of 30° North Latitude, only a proportion of the lifeboats, to be fixed by the Board of Trade, need be equipped with masts and sails.

The controlling instructions relating to the details of equipment associated with wireless telegraphy and searchlights are such as to ensure a high standard.

Shipowners and masters are responsible for keeping the life-saving appliances, including the lifeboat wireless installation, on board their ships in such a condition as to be at all times ready and fit for use. Tests of the installation are, therefore, carried out by the wireless operators once a week when at sea and once a month when the ship is in port. Entries are made in the official log-book on every occasion the life-saving appliances are examined and when the periodical tests of the wireless installation take place.

Mechanically Propelled Lifeboats.

Subject to the construction of these boats complying in all respects with the rules of the Board of Trade they are accepted as forming a part of the statutory equipment of a passenger ship. The propelling gear must be such that the boat can be manœuvred away from the ship's side expeditiously and maintain steerage under adverse weather conditions.

The arrangement of levers connected to the driving shafts operating the gear attached to the propeller is such that persons of different stature and untrained in the use of oars or mechanism can propel the boat without any re-adjustment of the gear. The fitting of the levers must not interfere with the rapid availability of the lifeboats when embarking passengers.

A reduction in the number of oars is accepted for this type of lifeboat, but additional internal buoyancy air cases are fitted to compensate for the weight of the propelling gear.

Illustrations of the "Fleming" boat fitted with the patent propelling apparatus are shown in Figs. 5 and 6.

Buoyant Apparatus.

As previously stated in this paper, buoyant apparatus forms a part of the statutory equipment, and the installation must be sufficient to support 25 per cent. of the total number of persons which the ship carries, or is certified to carry, whichever is the greater.

Detailed requirements have been embodied in the Board of Trade regulations, but the important features are as follows:—

> The apparatus must be effective and stable when floating either way up, and of such construction as will stand being man-handled and thrown from the deck into the water without damage. The apparatus is constructed under the inspection of the Board's surveyors and tested for stability and strength, after which a certificate of approval is given. It is marked for the intended number of persons and periodically tested when in service at the annual surveys.
>
> The apparatus is stowed in such positions as will not interfere with the launching of the lifeboats, or other buoyant apparatus, or the embarkation and marshalling of the passengers.
>
> The various units must always be readily available in case of emergency, and stowed on a deck clear of an upper superstructure. The means of securing them in position is by the aid of lashings which can be slipped easily. Not more than five units are permitted in any one tier, and provision is made to prevent the upper tier from sliding off the lower.
>
> Plans of the stowage are submitted for approval.

An interesting departure from the usual type of buoyant apparatus which has been approved by the Board of Trade is to be seen in Fig. 8. and named the Flotanet. The apparatus provides a floating platform of net formation associated with cork floats, and is rolled up for stowage on the upper deck. The apparatus varies in size to suit the size of ship, the largest being certified for 75 persons.

Line Throwing Appliances.

In 1928 an addition was made to the Statutory Rules relating to Life Saving Appliances, by making it compulsory for passenger ships of 500 tons gross tonnage and above, when proceeding on a voyage or excursion from a port in the United Kingdom, to carry an approved line-throwing appliance.

Certificates of approval are granted to makers of the apparatus by the Board of Trade.

The appliance is defined in the Rules as one consisting of :—

(*a*) Four 2-lb. line-throwing rockets with suitable sticks, or other apparatus, capable of throwing a line $\frac{5}{16}$ in. in circumference, a distance of 120 yds. in calm weather; and

(*b*) Two such lines, $\frac{5}{16}$ in. in circumference, each not less than 240 yds. in length, having a breaking strain of not less than 150 lbs.

There is nothing of interest to add in regard to the general equipment of lifebuoys, lifejackets, and the various details carried in the lifeboats. Development is to be seen, however, in the quality of the articles, rather than any fresh additions to the statutory requirements, beyond the provision of 1 lb. of condensed milk for every person the lifeboats are certified to carry.

Embarkation of Passengers.

Particular care is exercised in arranging the boat decks of new passenger ships so as to provide not only sufficient stowing space for all the lifeboats and buoyant apparatus, but also sufficient space in addition, to allow the boats to be cleared from the stowing positions expeditiously.

The arrangements for the control of passengers from the ship into the boats, are carefully considered in regard to the ingress to and egress from the different compartments, decks, etc., to the embarkation stations, where the passengers are transferred to the lifeboats rapidly and in good order.

Provision is made for ladderways and stairways to be suitably placed for the ready access of all classes of passengers to the embarkation decks under emergency conditions, and for controlling them and finally embarking them, through gateways in the side rails, bulwarks or side plating, into the boats.

Efficient arrangements are provided for keeping the lifeboats close to the ship's sides while the passengers are embarking, and for releasing them under control when they are loaded and ready for lowering.

Side ladders are carried of an approved type, one ladder for each set of davits, with sufficient length to reach the water line with the ship at her lightest sea-going draught, and listed 15 degrees either way.

These ladders are at least 18 ins. wide, with steps of hard wood having a tread of not less than 4 ins. wide, and arranged to prevent tripping. They are stowed at the embarkation decks or other suitable positions at the ship's sides. (*See* Fig. 6.)

The purpose of the ladders is to provide a means of access to the boats afloat for passengers who were unable to secure a seat in the lifeboats before embarkation, and to give better facilities for the crew operating the lowering of the boats from the deck to gain access to the lifeboats afloat without the necessity of sliding down the lifelines from the davit heads.

To facilitate the effective control and marshalling of the passengers, and to provide means of quick and uninterrupted access to the embarkation stations, and to reduce the possibility of panic, the exits and passages from every main compartment occupied by passengers or crew, to the embarkation and boat decks, are provided with a safety lighting system for illumination. Each exit is lighted continuously by an emergency lamp.

A proper system of lighting is provided on the decks where the boats, life rafts and buoyant apparatus are stowed, and so arranged as to provide adequate illumination to the inside of lifeboats during the process of the preparation of launching. In addition, in the case of passenger ships, where the height of the boat deck above the water line at the lightest sea-going draught exceeds 30 ft., the safety lighting system is extended to give adequate illumination at the ship's sides in order to facilitate the operation of launching the boats and enable them to get away from the ship's sides expeditiously.

The safety lighting generating system is independent of the main lighting supply and situated above the bulkhead deck, but it is also connected to the main generating plant. It is capable of being switched on instantly, and gives satisfactory illumination for a period of at least three hours if more boats than one are operated by any one set of davits, or for two hours if single boats only are stowed under davits.

Plans of the lighting arrangements, means provided for access to embarkation stations, and boat stowage are submitted for the approval of the Board of Trade.

Musters and Drills.

Standard regulations have been issued by the Board of Trade relating to musters and drills on passenger steamers, in order that members of the crew may be trained in the duties they would be required to undertake in the event of any casualty at sea.

The master of the ship is responsible for the preparation of the Muster List, which indicates the number and names of the crew assigned to the lifeboats, including the specified number of certified lifeboatmen. A deck officer, or certified lifeboatman, is appointed to take charge of each lifeboat, and also a second-in-command. A man capable of working the motor is assigned to each lifeboat and also one experienced in the working of the wireless and searchlight installation fitted to the motor boat. The arrangements made for marshalling the passengers at the embarkation stations are given in detail.

This list is posted conspicuously in various parts of the ship where it can be studied by the crew.

Alarm signals are given by a succession of six short blasts, followed by one long blast on the steam whistle or siren. This scheme is supplemented in ships supplied with a general safety certificate by electrically operated signals throughout the ship controlled from the bridge.

Crews are drilled in the duties connected with an outbreak of fire, the closing of doors, side scuttles, etc., marshalling of passengers and the launching of boats.

Emergency practices are required to be held weekly when practicable, and before the ship leaves port when the voyage will be for more than a week. A practice muster of passengers is held within twenty-four hours of the commencement of each voyage.

Particulars of all practices are recorded in the official log-book and the reasons for any weekly drill being omitted must be explained.

Particular care is taken of the "accident" boats carried near the navigating bridge, the crews of which are mustered at least three times a week during the period the vessel is at sea. The full equipment of the boats is overhauled each day, and a lighted lamp is placed in each boat every night.

Conclusion.

When reading through the foregoing descriptive sections of this paper one cannot help being impressed with the high standard of construction incorporated in large British passenger ships, and the careful forethought which has been displayed in dealing with the details of life-saving equipment. Every precaution has been taken to meet all the difficulties which it is humanly possible to forsee a ship might meet as a result of casualty at sea.

The British standard of safety of life at sea is now the standard of the world's shipping, it was the standard which formed the basis for agreement in the International Conventions, and it now remains to be seen whether the signatories of these agreements will exercise the necessary oversight to maintain this standard which is rigidly observed by the British owners of large passenger ships.

In bringing to a conclusion this portion of the paper some details of the lifeboat equipment fitted on the Queen Mary and the Normandie are given as examples of the development in this respect on large passenger ships.

Queen Mary.—The following lifeboats are carried at the ship's sides in single tier under gravity davits, supplied by Messrs. Samuel Taylor & Sons, and operated by single wire falls in association with Ferguson's boat releasing gear.

There are 24 sets of davits, under which are :—20 motor lifeboats, 36 ft. by 12 ft. by 5 ft., each accommodating 145 persons; two motor lifeboats, with wireless, etc., 36 ft. by 12 ft. by 5 ft., each accommodating 130 persons; two accident lifeboats, 30 ft. by 9 ft. 3 ins. by 3 ft. 10½ ins., each accommodating 44 persons. The total accommodation is for 3,248 persons.

The boats are of steel, and were constructed by Messrs. Hugh McLean & Sons, of Govan, the shape and fittings being arranged to facilitate rapid embarkation. The details of one of the lifeboats is seen in Fig. 7. This is one of the two motor lifeboats fitted with wireless telegraphy. The small mizen is fitted to assist in keeping the head of the boat steady in a seaway when riding by the sea anchor.

Each of the 36 ft. lifeboats is fitted with Diesel machinery, supplied by Messrs. John Thornycroft & Co., Ld., consisting of two-cylinder engines developing 18 H.P. at 1,200 r.p.m., and fitted with reduction gear.

To comply with the requirements as previously outlined in this paper, it is interesting to note that the engine is enclosed in a watertight casing which is lagged with asbestos in order to keep out the cold and retain the heat supplied by a non-flame type of heater. The heater is connected to a plug to the ship's current, and when the lifeboat is launched the contact is automatically disconnected. All the controls and starting handles are fitted outside the casing. A water cooling supply is installed which enables the engine to be kept in condition by periodical running, and it is possible to start the engine before the lifeboat is water borne, thus enabling the boat when afloat to get away from the ship's side immediately. Two of the motor lifeboats are equipped with wireless telegraphy and a searchlight.

The whole of the lifeboat equipment, being in single tier, can be put into the water at the first operation, without the necessity of recovering the falls for a second tier of lifeboats.

NORMANDIE.—Thirty gravity davits are installed to the designs of Messrs. Welin-Maclachlan Davits, Ld., of London and Glasgow.

There are 26 lifeboats, 30 ft. by 10 ft. 6 ins. by 4 ft. 5 ins. accommodating 88 persons in each.

Twenty-six lifeboats, 24 ft. 4 ins. by 8 ft. 2 ins. by 3 ft. 5 ins. each accommodating 46 persons are nested in the 30 ft. lifeboats and carried under the same davits.

In addition, there are two motor boats and two "accident" boats.

The total number of persons accommodated in the boats is 3,582.

The large boats were constructed to the designs of Messrs. Hugh McLean & Sons, Ld., and the planking is of mahogany in two thicknesses.

The 26 ft. lifeboats are lowered from the davits in the first operation, and having single wire falls a quick return is made for launching the second tier of 24 ft. lifeboats. With the exception of the motor boats and "accident" boats, the Lactetia-Echard patent lever propulsion is fitted to all the lifeboats.

The disengaging gear is Messrs. Mills' patent, and 52 of the boats are fitted with Schat patent skates.

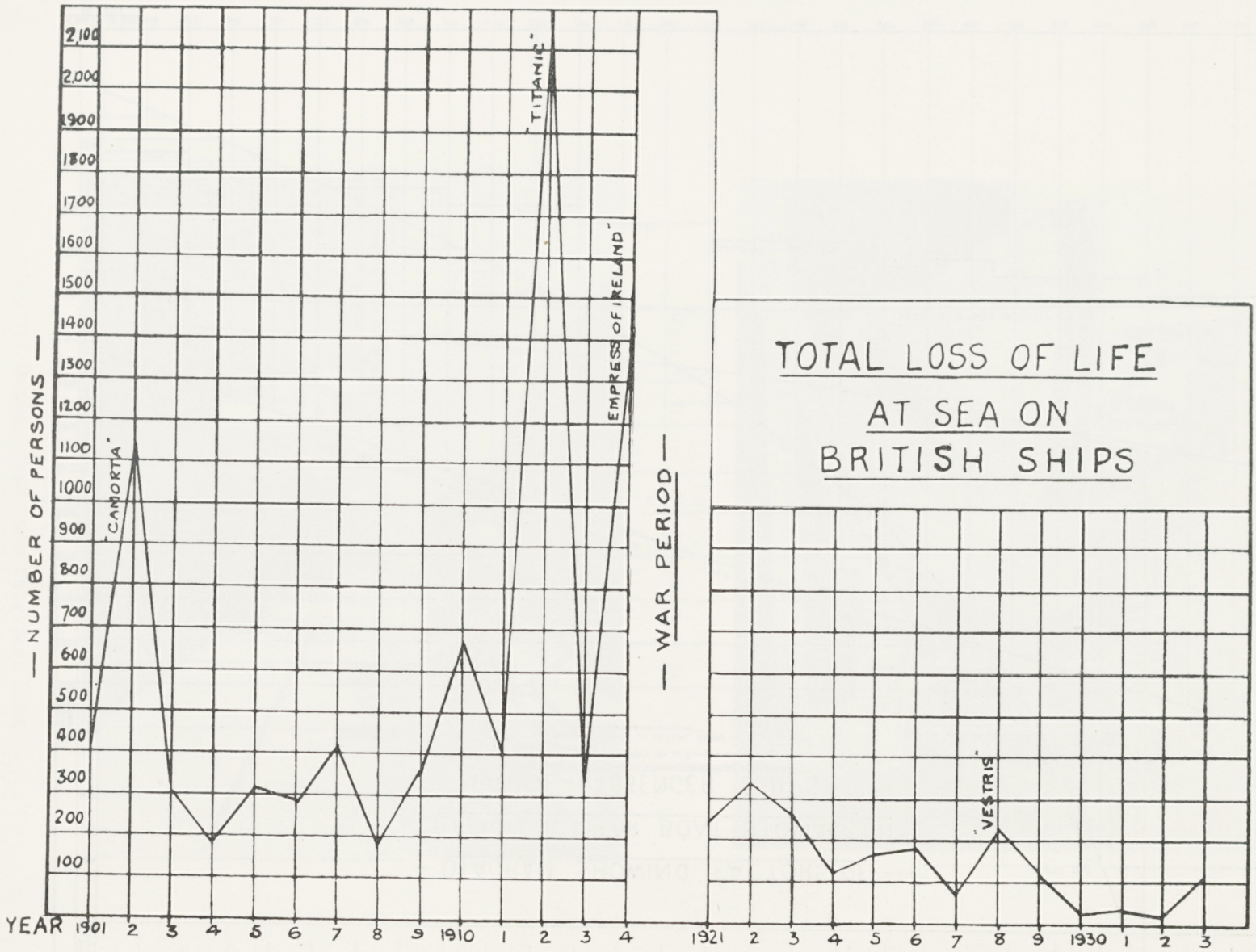

TOTAL LOSS OF LIFE
AT SEA ON
BRITISH SHIPS
— NUMBER OF PERSONS —
2,100
2,000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
"CAMORTA"
"TITANIC"
"EMPRESS OF IRELAND"
— WAR PERIOD —
"VESTRIS"
YEAR 1901 2 3 4 5 6 7 8 9 1910 1 2 3 4 1921 2 3 4 5 6 7 8 9 1930 1 2 3

FIG. 1.

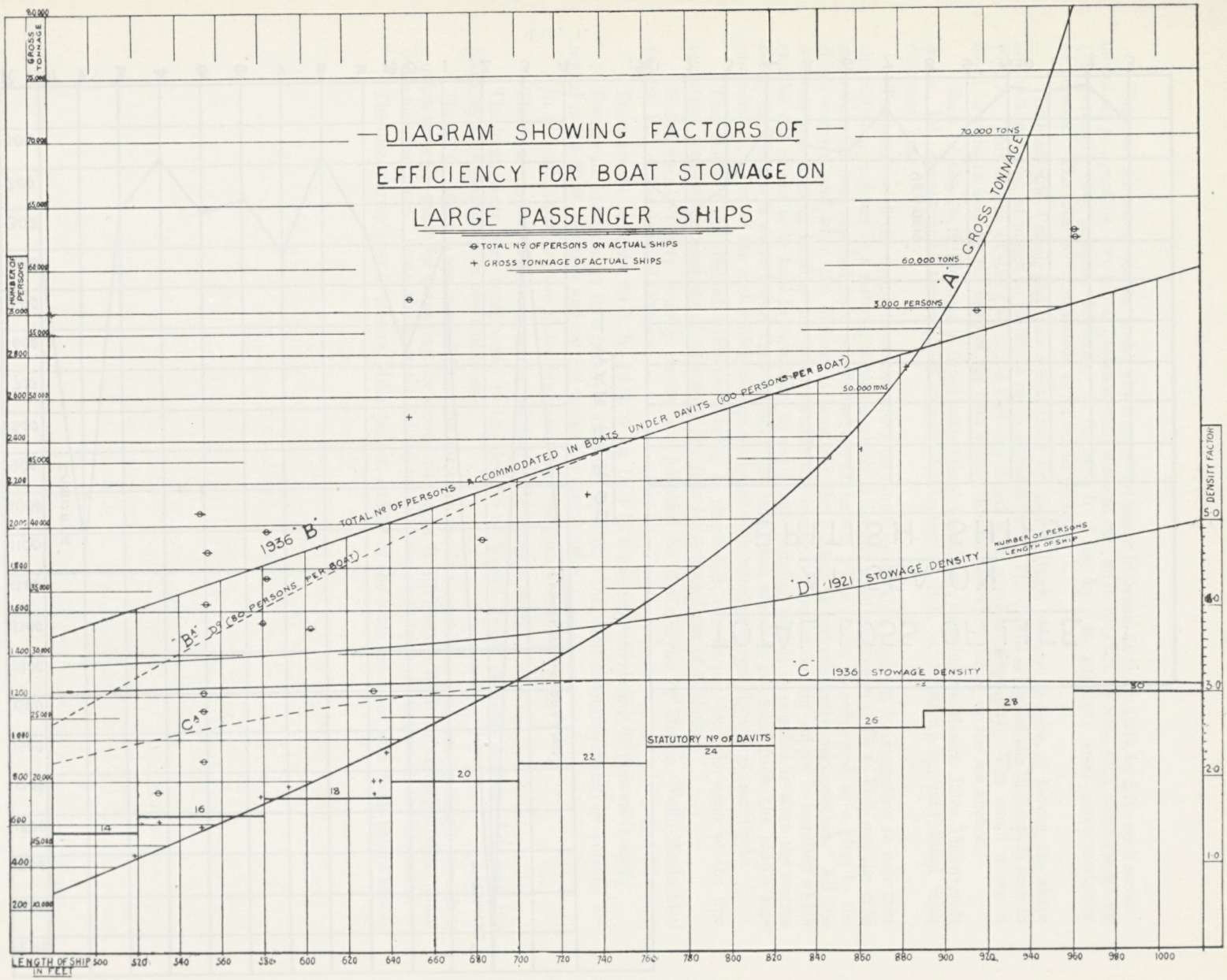


DIAGRAM SHOWING FACTORS OF
EFFICIENCY FOR BOAT STOWAGE ON
LARGE PASSENGER SHIPS
TOTAL Nº OF PERSONS ON ACTUAL SHIPS
GROSS TONNAGE OF ACTUAL SHIPS
GROSS TONNAGE
NUMBER OF PERSONS
DENSITY FACTOR
70,000 TONS
60,000 TONS
50,000 TONS
3,000 PERSONS
'A' GROSS TONNAGE
1936 'B' TOTAL Nº OF PERSONS ACCOMMODATED IN BOATS UNDER DAVITS (100 PERSONS PER BOAT)
'B' 1921 (80 PERSONS PER BOAT)
'C' 1936 STOWAGE DENSITY
'D' 1921 STOWAGE DENSITY
NUMBER OF PERSONS / LENGTH OF SHIP
STATUTORY Nº OF DAVITS
24
22
20
18
16
14
26
28
30
LENGTH OF SHIP IN FEET
500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820 840 860 880 900 920 940 960 980 1000

FIG. 2.

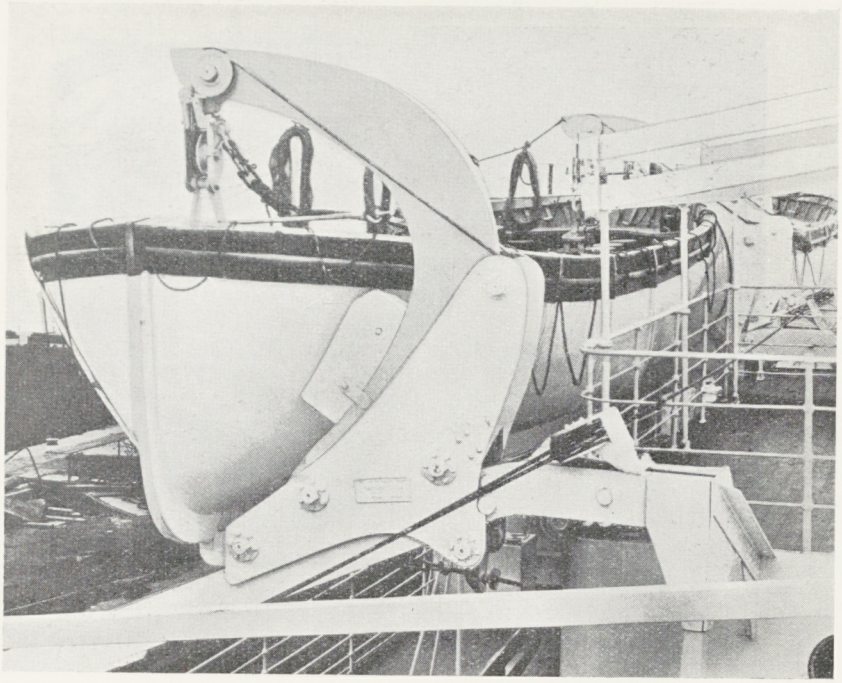


FIG. 3.
GRAVITY DAVITS. VIEW FROM BOAT DECK.

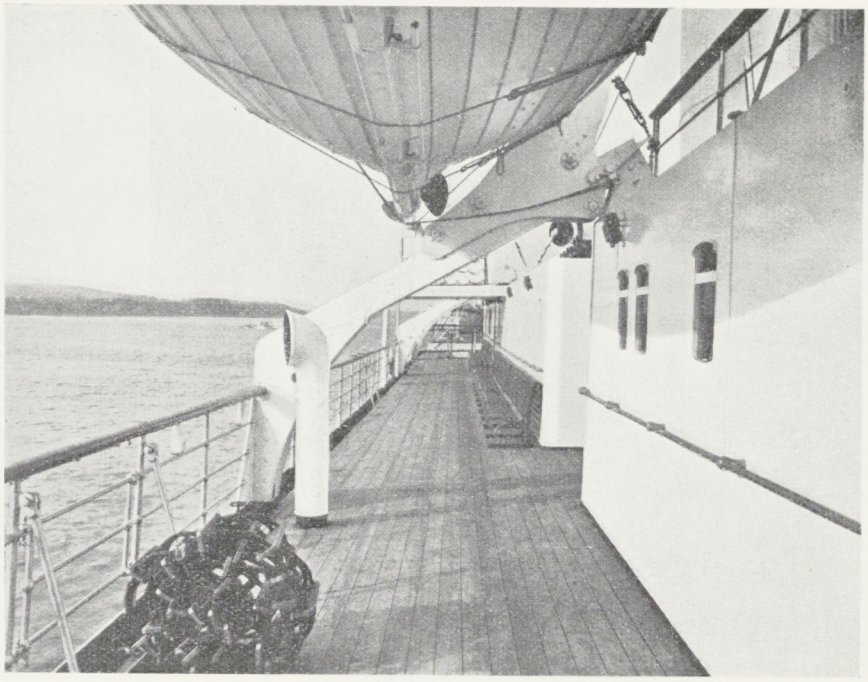


FIG. 4.
GRAVITY DAVITS. VIEW FROM PROMENADE DECK.

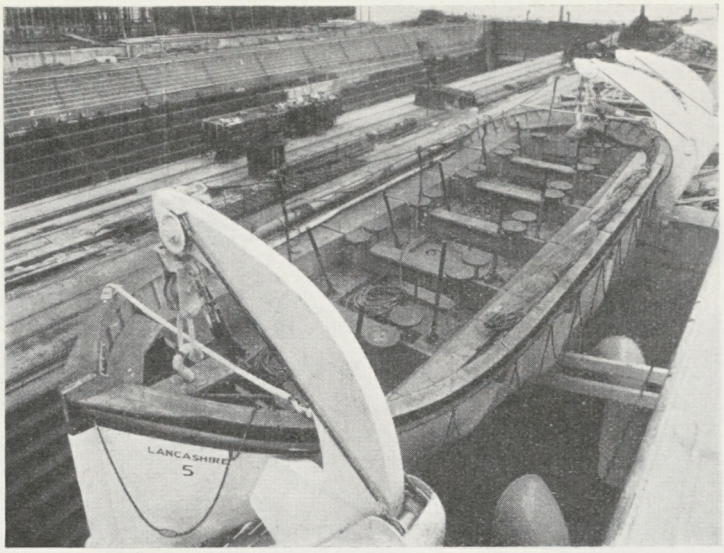


FIG. 5.
MECHANICALLY PROPELLED LIFEBOAT UNDER GRAVITY DAVITS.

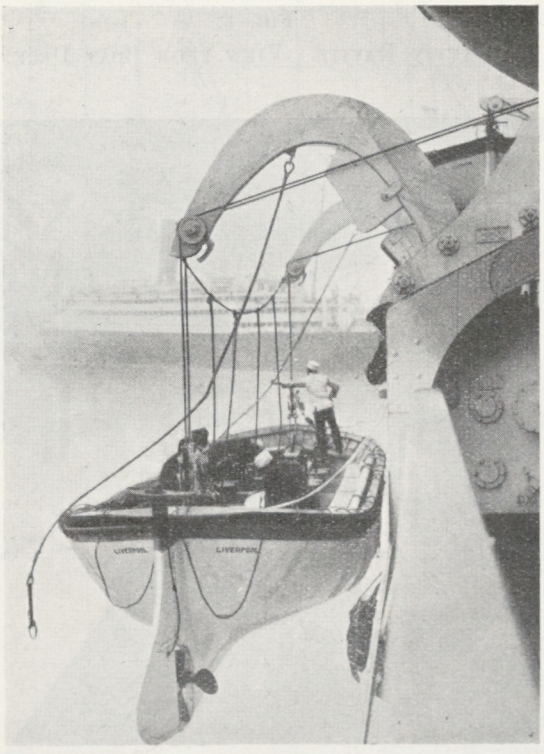


FIG. 6.
GRAVITY DAVITS IN THE OUTBOARD POSITION.

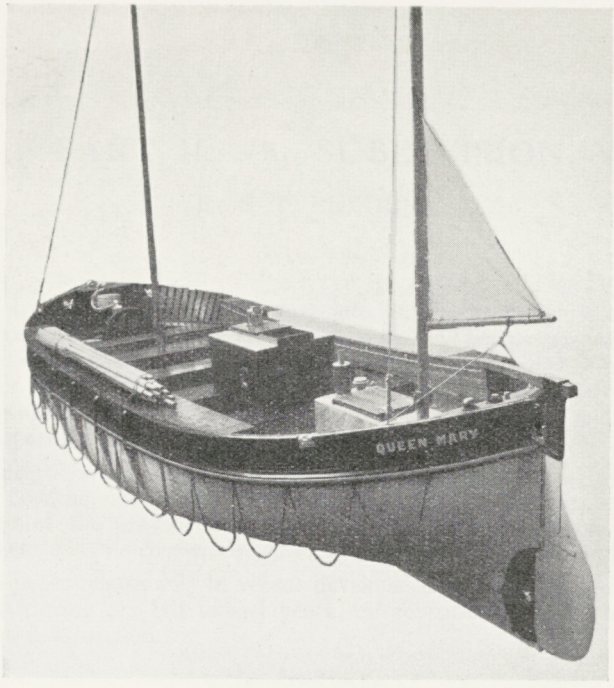


FIG. 7.

36 FT. MOTOR LIFEBOAT EQUIPPED WITH WIRELESS TELEGRAPHY FOR THE "QUEEN MARY."

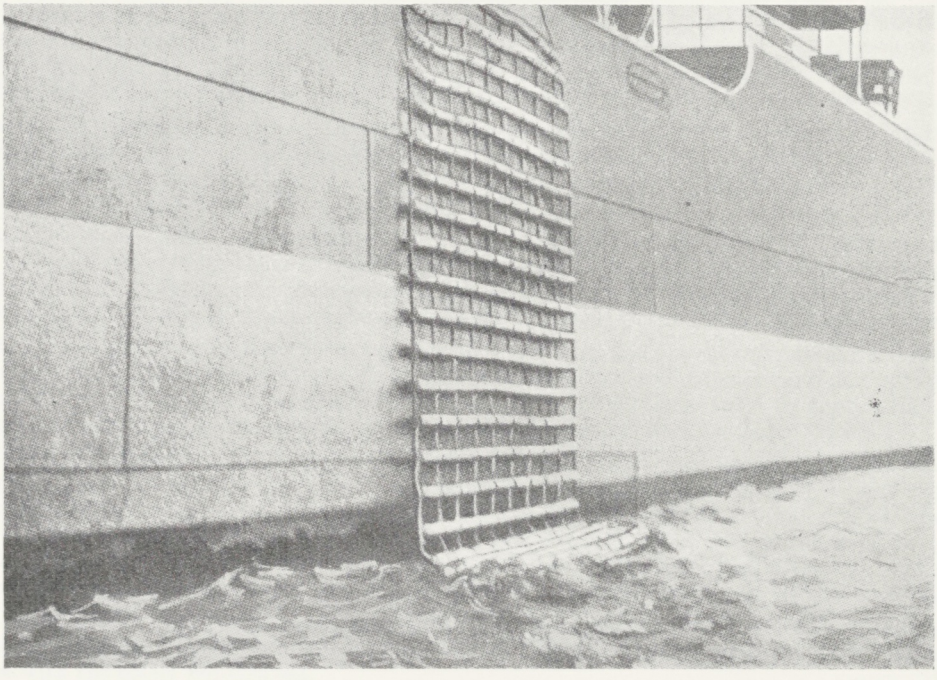


FIG. 8.

"FLOTANET" BUOYANT APPARATUS LAUNCHED DOWN SHIP'S SIDE.

PART II.—(b) SUBDIVISION.

By S. T. BRYDEN.

Subdivision, or the division of the hull of a ship into watertight compartments, is undertaken with a view to providing a reasonable margin of safety for the vessel and her passengers and crew, in the event of the accidental penetration of water into the hull. The greater the number of compartments into which a ship is subdivided the greater is her comparative safety, but unfortunately the greater also is the inconvenience in the stowage of cargo, in the distribution of the machinery, and in intercommunication between the passenger spaces, so that a compromise has to be made.

The permissible length of a compartment depends upon many factors, for example, the form of the ship, the draught before flooding, the permeability of the compartment (i.e., the extent to which it may be flooded, taking into account the presence and nature of the cargo, etc., therein) and the fore-and-aft position of the compartment with its consequent effect upon loss of buoyancy and trim.

As the scope of this paper relates only to recent developments, it is proposed to give a brief history of subdivision legislation during the last twenty years, before considering the technical changes which have been produced by such legislation.

I.—History,

Following upon the loss of the Titanic in April, 1912, the Board of Trade appointed a Departmental Committee to advise generally upon the subject of subdivision, and in November, 1913, an International Conference on the Safety of Life at Sea met in London and drew up a Convention. The latter was applied to this country by the Merchant Shipping (Convention) Act of 1914, which was to have come into force on the 1st July, 1915, but this was postponed owing to the Great War. The Convention laid down rules for all ships carrying more than twelve passengers. Two standards of subdivision were defined, the maximum standard applying to vessels mainly engaged in carrying passengers (called the "passenger" type) and the minimum to vessels carrying both passengers and cargo (called the "mixed" type). The standard for a particular vessel was to be determined by its relation to the two types.

Although the Merchant Shipping (Convention) Act was not put in force, the Board of Trade in 1915 issued "Instructions relating to the Construction of Passenger Steamships," applying the standard laid down in the Convention for the "mixed" type to all "new" foreign-going passenger ships (i.e., those, the keels of which would be laid on or after 1st January, 1916).

In practice it soon became apparent that the standard adopted by the Board of Trade was too high for the "mixed" type of ship which carried relatively few passengers, and the outcome of conversations in Washington in 1920 between representatives of the British and United States Governments, was an alternative standard of subdivision permitted by Board of Trade Circular No. 1623 of October, 1920.

This, however, afforded no basis for a permanent settlement, and the Board referred the matter for final solution to an informal Committee. The findings of the latter were adopted, and new "Instructions as to the Survey of Passenger Steamships" were issued in 1928, these rules to apply to all "new" foreign-going passenger ships, the keels of which would be laid on or after 1st July, 1928.

In 1929, an International Convention assembled in London and drew up provisions for promoting the safety of life at sea, including the subject of sub-division. The regulations of this Convention were adopted by the British Government and embodied in the Merchant Shipping (Safety and Load Line Conventions) Act of 1932, which came into force on the 1st January, 1933. Consequent upon this Act the Board of Trade issued a number of supplements to the 1928 edition of "Instructions as to the Survey of Passenger Steamships," Supplement No. 2 embodying all the modifications in regard to subdivision.

This is the present position, but it is the Board of Trade's intention in the not very distant future to issue a further complete edition of "Instructions as to the Survey of Passenger Steamships," amended in accordance with the above Supplement.

II.—Work of the Bulkheads Committee of 1912–15.

As a basis from which to describe the technical changes consequent upon the above progressive legislation, it will first be necessary to give some account of the scope and requirements of the 1915 "Instructions." These embodied regulations determining the subdivision of a vessel, the scantlings of the watertight bulkheads, and requirements regarding the position and closing of openings in the vessel's structure.

The work of the Bulkheads Committee, upon which the 1915 "Instructions" were based, involved the determination of flooding curves* for a large variety of passenger ships, and the analysis and presentation of the information so obtained in a form which would make it easily applicable to any particular vessel by a simple process. These flooding curves were determined for two different permeabilities† of compartment, viz., 60 per cent and 100 per cent. The Committee provided two sets of diagrams, one set for each of the two degrees of permeability, and each set comprises 12 diagrams, giving the ordinate of the floodable length curve at one of the 12 stations into which the ship's length is divided, in relation to the actual block-coefficient, freeboard ratio‡ and sheer-ratio§ of the vessel, the subdivision of which is being investigated. Reference may be made to these diagrams in Plates II to XXV of Volume II of "Instructions as to the Survey of Passenger Steamships, 1928."

Having determined the ordinates of the flooding curve for permeabilities of 60 per cent and 100 per cent, those for the actual permeabilities of the vessel under consideration were to be found by interpolation. For this purpose the vessel was to be considered in three sections, viz., the after body, the machinery space, and the fore body, respectively, the mean permeability of each of these portions of the vessel being separately determined.

The floodable length diagrams provided by the Bulkheads Committee were based on assumed standard forms, and a simple method was provided whereby the flooding curve ordinates, now corrected for permeability, could next be modified for change of form to suit the actual vessel of which the subdivision was being investigated. This took account of the sectional area, moment of inertia and position of the centre of flotation of the "mean waterplane"‖ of the actual ship, as compared with those of the mean waterplane of the standard vessel upon which the diagrams were based, having the same block-coefficient and freeboard-ratio.

In order to ascertain the degree of subdivision required for a particular vessel, the Committee provided two curves indicating the appropriate "Factor of Subdivision" which should be applied to the ordinates of the floodable length curves, in order to ascertain the permissible length of the compartments. These curves were denominated "B" and "C," and applied to vessels up to 900 ft. in length. Curve "B" referred to ships of the "mixed" type, i.e., those carrying both cargo and passengers, and required a one-compartment standard in the case of vessels 295 ft. in length, and two and three-compartment standards for vessels of 571 and 900 ft. in length, respectively. Curve "C" referred to ships of the "passenger" type, i.e., those mainly engaged in the transport of passengers, and required a one-compartment standard for vessels of 258 ft. in length, a two-compartment standard for vessels of 490 ft., and a three-compartment standard for vessels of 800 ft. and over. For a vessel of a type intermediate between the "mixed" and "passenger" standards, the factor of subdivision was to be obtained by interpolation between curves "B" and "C," on the basis of a Criterion of Service numeral indicating the relation which the ship under consideration bore to the respective standards.

---

* The ordinate of a flooding curve at any point represents the length of the watertight compartment having its middle of length at that point, which, when flooded, would cause the ship to sink and trim to a waterline tangential to a margin line drawn parallel to, and 3 ins. below, the bulkhead deck. This floodable length is expressed as a percentage of the vessel's length.

† The permeability of a compartment is the percentage which can be occupied by water.

‡ The freeboard ratio is the ratio of the vessel's freeboard to her draught.

§ The sheer-ratio is the ratio of the vessel's sheer at the forward or after perpendicular to her draught, for the forward and after body ordinates, respectively. In the case of vessels having sheer of other than the standard parabolic form, with the lowest point amidships, as contemplated by the rules, the Committee required a correction to be made before determining the sheer-ratios.

‖ The mean waterplane is that midway between the subdivision load waterplane and one parallel thereto touching the margin line at its lowest point.

III—1915 Instructions.

In their 1915 Instructions, the Board of Trade adopted all the above recommendations of the Bulkheads Committee, with the exception of that relating to a factor of subdivision dependent upon a criterion of service numeral. Instead they adopted for all foreign-going passenger vessels the factor of subdivision curve "B", viz., that recommended by the Committee for the "mixed" type. (This is indicated in Fig. 1.)

The following are some of the more important details of the 1915 Instructions:—

Permeability. (*a*) *In way of the machinery space.* For steamships the permeability was to be taken at 80 per cent., and for motorships at 85 per cent.

(*b*) *Spaces forward of and abaft the machinery space.* (i) For all cargo spaces, bunkers, storerooms, baggage and mail rooms, chain lockers, W.T. shaft or pipe tunnels, and fresh water tanks above the double bottom, the permeability was to be taken at 60 per cent.

(ii) For passenger and crew spaces, peaks and double bottoms the permeability was to be taken at 95 per cent. The average permeability of the spaces forward of and abaft the machinery space was to be determined independently by the formula $95-35\ r$, where r was the ratio between the volume of spaces mentioned above in (i) and the total volume of the space under consideration.

Permissible Length of Two Adjacent Compartments. When the factor of subdivision was ·5 or under, the Instructions permitted it to be doubled in order to give the length of two adjacent compartments, but the smaller of these was not to be less than 25 per cent. of the combined length, and this method was to be applied to each adjacent pair of compartments throughout the length of the ship.

Upper Limit of Length of Compartment. No watertight compartment was to exceed 92 ft. in length.

Lower Limit of Length of Compartment. In large vessels, no compartment (included in the subdivision) was to be less than 10 ft. in length for at least one-quarter of the ships breadth inboard from the side.

Limit of Length of Two Foremost Compartments. When the factor of subdivision was less than ·84 but greater than ·50, the combined length of the two foremost compartments was not to exceed the floodable length at the forward end, provided also that the second compartment was neither greater than the permissible length nor less than 10 ft.

Additional Subdivision at the Forward End of Large Vessels. In the case of ships of more than 699 ft., but less than 823 ft. in length, the floodable length at the forward end was to be at least 20 per cent, and the ship forward of a bulkhead placed either at the distance of the actual floodable length from the stem, or not nearer than 20 per cent, was to be divided into at least three compartments. In the case of ships of 823 ft. and over, the floodable length was to be at least 28 per cent, and the number of compartments at least four.

Recesses and Steps in Bulkhead. Recesses were permitted in transverse bulkheads, provided the sides of the recess were placed at a sufficient distance inboard from the sides of the ship. This distance was made dependent upon whether the factor of subdivision was greater than ·5 or not. (*See* Fig. 2.) Vertical steps were not permitted in the main transverse watertight bulkheads of ships having a factor of subdivision greater than ·5, unless arrangements were made by additional subdivision to maintain the same measure of safety as that in the bulkhead without a step. Steps, where permitted, were limited to a total length of $\cdot 02\ L + 10$ ft.

Peak and Machinery Space Bulkheads. A collision bulkhead was to be fitted not less than 5 per cent of the vessels length from forward, and was to extend to the bulkhead deck, or to the weather deck in ships having continuous superstructures. Bulkheads separating the machinery space from the cargo and passenger spaces were to be fitted extending to the bulkhead deck, and an after peak bulkhead was to be fitted, but might be stopped below the bulkhead deck, provided that it was carried up to the first deck above the load waterline, and that this deck formed a watertight flat to the stern. Stern tubes were to be enclosed in watertight spaces.

Exits from Watertight Compartments. In passenger and crew spaces an exit was to be provided from each watertight compartment, and also from each engine-room, stokehold and shaft-tunnel, independently of the watertight doors.

Openings in Watertight Bulkheads and Watertight Doors. Openings in watertight bulkheads were to be reduced to a minimum, and satisfactory means of closing the openings were to be provided. No openings were permitted in collision bulkheads below the margin line. No openings were permitted in any transverse watertight bulkhead separating one cargo space from another or from a reserve bunker, except in 'tween decks situated above the waterline for the whole length of the ship, where specially heavy hinged watertight doors, always securely closed at sea, were permitted. Hinged watertight doors were also permitted in passenger, crew and working spaces above a deck, the lowest point of which was at least seven feet above the load waterline. Plate doors secured by bolts were only permitted in the machinery spaces, and were always to be jointed watertight before the ship left port. All other watertight doors were to be of the sliding type, and although six types were specified, they may be divided into three main classes :—

(i) those operated by hand, locally and from above the margin line ;
(ii) those dropping by their own weight and released by an approved apparatus, and
(iii) those controlled by power from the bridge.

Hand-operated doors were permitted above the load waterline, but for those situated below the load waterline, the Instructions indicated the type to be fitted, this being dependent upon the number of doors in the machinery space at about the stokehold level (other than those at the entrances to tunnels) and upon the number of passengers carried. Not more than one watertight door was permitted in each transverse bulkhead in the machinery space for purposes of intercommunication (i.e., other than those for bunkers and shaft tunnels).

Sluice valves were to be reduced to a minimum and were only permitted where always accessible, and were to be controlled from above the margin line.

Side Scuttles. Side scuttles were not permitted in any space exclusively used for coal or cargo. Side scuttles situated below a deck, the lowest part of which, at any point in the ship's length, was less than 7 ft. above the subdivision load line were to be permanently fixed, unless they were closed and locked before the ship left port, and were not opened during navigation. Opening side scuttles were permitted in positions above the deck described above. Inside hinged deadlights were to be fitted to all permanently fixed sidelights, to those which were to be kept closed during navigation, to those situated within the forward one-eighth of the ship's length, below the bulkhead deck, and to those in all spaces below the bulkhead deck used to accommodate seamen and firemen. In spaces below the above deck used for the accommodation of passengers, officers, stewards or similar ratings, inside hinged deadlights were to be fitted unless the vertical distance of the sill of the side scuttle above the loadline was at least equal to a specified distance, which was dependent on the breadth of the vessel. If this distance was exceeded, portable plugs were permitted instead of hinged deadlights.

Inlets and Discharges. Main or auxiliary inlet valve chests were to be made as short as possible and to be attached to special wrought steel boxes built on to the skin of the ship where necessary to avoid a long neck. Such inlets or discharges were to have accessible cocks or valves fitted between the pipes and the ship's sides or bottom.

Scuppers, Sanitary Discharges, Etc. Side openings were to be reduced to a minimum by the grouping of the discharges. The discharges through the skin were to be provided with either one automatic non-return valve with positive control from a distance, or two valves without such control, one of which was to be an automatic non-return valve. The outer valve was to be enclosed in a strong valve box on the ship's skin, and all valves or their controls were to be accessible at all times and situated above a deck the lowest point of which was at least 7 ft. above the loadline. All sanitary discharge and scupper pipes were to have elbows of metal other than cast iron or lead, and pipes were not to be fitted in a direct line between their ship's side openings and connections with the deck or sanitary appliances. Pipes and valves were to be protected in cargo holds by casings.

Ash Shoots (other than Ejectors), Rubbish Shoots, Etc. The inboard ends of such shoots were not to be lower than a deck which at its lowest point was less than 7 ft. above the subdivision loadline, and were to be fitted with efficient covers, watertight if below the margin line.

Double Bottoms in large ships were to extend all fore and aft between the peak bulkheads, or as near thereto as practicable, and the inner bottom was to be continued out to the ship's side in such a manner as to protect the bilges, and if the outer end of the margin plate was lowered for drainage purposes the line of intersection with the bilge plating was not to be less than $2\frac{1}{2}$ per cent of the vessel's

breadth above the rise of floor line. (*See* Fig. 3.) In ships over 699 ft. in length the double bottom was to extend up the ship's sides to a height of 10 per cent of the moulded breadth, for at least half her length amidships and forward to the collision bulkhead. Wells for drainage purposes were not to extend downwards more than half the depth of the double bottom, except at the after end of shaft tunnels.

Watertight Decks. These were not permitted below the level of the subdivision loadline. Where fitted above that level, but below the level of the bulkhead deck, in vessels having a factor of subdivision of less than ·45, the factor for the compartments in way of the watertight deck could be increased by ·05 to a maximum of ·45.

Longitudinal Subdivision. Watertight longitudinal bulkheads or inner skins were permitted, provided that it could be shown that, if the longitudinal compartment on one side of the ship were flooded for a length equal to the floodable length at that part, the margin line would not be submerged, and the ship would not take a list which would render it difficult to utilise all the vessel's boats or to maintain her navigability, or, if such a list would be produced, approved arrangements were fitted for counteracting it. In ships having a factor of subdivision less than ·45, fitted with an inner skin or longitudinal bulkhead placed not nearer the side than ·02 B + 2 ft., and extending to a deck above the load line, the crowns of the side compartments being watertight, and the arrangement complying with the above conditions regarding non-submersion of the margin line and provision against dangerous list, the factor of subdivision for the transverse compartment in way could be increased by ·05 to a maximum of ·45.

Strength and Construction of Watertight Bulkheads, Decks, Tunnels, Trunks, Ventilators, etc. Tables were included in the Instructions giving the scantlings of bulkhead and tunnel stiffeners and plating, details of the end connections of stiffeners, and of the rivet spacing. Boundary angles were to be double riveted where the distance below the bulkhead deck exceeded 24 ft., and the vertical connections of plates were to be double riveted where the depth below the bulkhead deck exceeded 35 ft. Watertight decks, trunks and ventilators were to be of the same strength as the watertight bulkhead at the place where they occurred, the thickness of watertight decks being ·04 in. thicker than that required for bulkheads at the same level.

IV.—Circular No. 1623 of October, 1920.

The above Circular was the outcome of conversations in Washington, as it was considered that the curve of factors of subdivision imposed by the 1915 Instructions was too severe on vessels of the mixed type. The Circular gambled on the probability that a vessel, if bilged, would be bilged at the forward end, and permitted, as an alternative to the factors of subdivision of the 1915 Instructions, that if the severity of the subdivision were increased at the forward end of the vessel it could be relaxed elsewhere. The factors of subdivision permitted by the Circular are indicated in the following table, and the curve of factors for compartments abaft No. 2 hold is indicated in Fig. 1. This Circular only applied to vessels between 410 and 570 ft. in length and was optional.

Length of Vessel in Feet.	FACTORS OF SUBDIVISION.		
	Fore Peak and No. 1 Hold together.	Nos. 1 and 2 Holds together.	Remainder of Vessel.
410	·90	...	·90
440	·90	·90	·90
480	·90	·90	·88
510	·90	·90	·81
540	·90	·90	·70
570	·90	·90	·60

The Circular did not modify the 1915 Instructions in any other way.

V.—1928 Instructions.

These Instructions were complete in themselves and replaced those of 1915, although many of the latter Instructions were embodied therein. With the amendments introduced in Supplement No. 2, of 1932, the 1928 Instructions are in force at the present time. Their general effect was to produce considerable relaxation in the subdivision of vessels of the "mixed" type (so that spacious holds were permissible once more), and a lesser degree of relaxation in the case of vessels more nearly approaching the full "passenger" type. As regards ship's side and bulkhead openings, the rules regarding these were in some cases revised, and the safety of the ship thereby increased.

The more important changes made by the 1928 Instructions are as follows :—

Permeability. (*a*) *In way of the machinery space.* Where no 'tween decks were fitted in the machinery space, the permeability remained 80 as in the 1915 Instructions, but if there were any 'tween deck spaces below the margin line within the limits of the machinery space, the average permeability $= 75 + 12{\cdot}5\,\frac{a}{v}$ where a = the volume of passenger and crew spaces in the 'tween decks, and v = the whole volume of the machinery space. In motorships, the permeability was to be five greater than that ascertained as above for steamships.

(*b*) *Spaces forward and aft of the machinery space.* The average permeability for each of these spaces was to be obtained from the formula $63 + 35\,\frac{a}{v}$ where a = the volume of the passenger and crew spaces below the margin line in the portion under consideration, and v = the whole volume of that portion.

Passenger and crew spaces for inclusion in the above formulæ were defined as those not used as cargo spaces, main and auxiliary propelling machinery spaces, bunkers (permanent, reserve or oil fuel), store rooms, baggage and mail rooms, chain lockers, watertight tunnels, fresh water, peak and other tanks.

This alteration considerably simplified the determination of the permeability of the portions of a vessel forward of and abaft the machinery space, and gave results not very dissimilar from those given by the 1915 Instructions.

Factor of Subdivision. Two curves of factors of subdivision were now provided as had been recommended by the Bulkheads Committee, for the "mixed" and "passenger" types of ship, respectively. The curves, however, which are indicated in Fig. 1, differed from the Committee's curves. That for the "mixed" type required a one-compartment standard in the case of a vessel 430 ft. in length and a two-compartment for a vessel of 790 ft., the latter, it will be remembered, being the standard required for a ship 571 ft. in length under the 1915 Instructions. The "passenger" curve required a one-compartment standard for a vessel 260 ft. in length, and two and three-compartment standards for vessels 493 and 900 ft. in length, respectively.

Criterion of Service Numeral. This was introduced for the first time as a means of interpolation for a particular ship between the factors of subdivision for the "mixed" and "passenger" types.

The Criterion of Service Numeral, $C_s = 72\,\frac{(M + P_1)}{(V + P_1 - P)}$ where P_1 was greater than P, or $72\,\frac{(M + 2P)}{V}$ in all other cases.

The symbols had the following meanings :—

M = the volume in cubic ft. of the machinery space below the margin line, including any permanent oil fuel bunkers above the inner bottom,
N = the total number of passengers carried,
P = the volume in cubic ft. of passenger and crew spaces below the margin line,
P_1 = ·6 LN cubic ft. or 200 N cubic ft., whichever was the greater (L being the length of ship in feet.)
V = the whole volume in cubic ft. of the ship below the margin line.

It will be seen that the 1928 Instructions for the first time related the degree of subdivision to the number of passengers carried.

Rules for Subdivision. Abaft the fore peak in all ships 430 ft. in length and upwards having a Criterion Numeral of 23 or less, the sub-division was to be governed by the factor for the "mixed" type, for those having a Criterion Numeral of 123 or more by that for the "passenger" type, and for those having intermediate Criterion Numerals by direct interpolation between the factors for the two types.

Upper Limit of Length of Compartment. The mean length of any transverse compartment was not to exceed ·05 L + 70 ft. For ships over 440 ft. in length this permitted longer compartments than did the 1915 Instructions.

Lower Limit of Length of Compartment. No compartment other than the peaks was to be less than ·02 L + 10 ft., as compared with 10 ft. under the 1915 Instructions.

Limit of Length of Two Foremost Compartments. In ships 430 ft. and more in length, one of the bulkheads abaft the fore peak was to be fitted at a distance not greater than the permissible length from the forward perpendicular. The rule requiring additional subdivision at the forward end of large vessels in the 1915 Instructions was omitted in those of 1928.

Recesses and Steps in Bulkhead. Recesses in transverse bulkheads were permitted, provided the sides of the recess were placed at a sufficient distance from the sides of the ship, but this distance was not governed by variation in the factor of subdivision as in 1915. (*See* Fig. 2.) The regulations relating to vertical steps remained unaltered.

Peak and Machinery Space Bulkheads. The collision bulkhead was to be placed not less than ·05 L, but not more than ·05 L + 10 ft. from the forward perpendicular. It was to be extended to the deck next above the bulkhead deck in ships having long forward superstructures. The after peak bulkhead might be stopped below the bulkhead deck, provided the degree of safely of the ship as regards subdivision, was not thereby diminished. Stern tubes were to be enclosed in watertight spaces, and in front of each stern tube stuffing-box bulkhead, either a complete watertight tunnel, or a watertight compartment not less in length than twelves times the diameter of the propeller shaft, was to be fitted.

Openings in Watertight Bulkheads and Watertight Doors. The instructions regulating the type of sliding watertight doors required to be fitted in positions below the low waterline, were now related to the Criterion of Service Numeral instead of directly to the number of passengers carried.

Openings in the Ship's Sides.—Side Scuttles. All side scuttles having sills less than 6 ins. above the deepest loadline were to comply with Board of Trade Circular, No. 1485 (under-water pattern sidelights). Sidelights situated below a deck, the underside of which at its lowest point was 7 ft. or more above the deepest subdivision loadline, were not required to be fixed, or closed watertight and locked during navigation, provided that they were not lower than if fitted immediately below a deck, which at its lowest point would be *exactly* 7 ft. above the deepest subdivision loadline. Efficient inside hinged deadlights were to be fitted (i) to permanently fixed side scuttles; (ii) to side scuttles fitted within one-eighth length from the forward perpendicular; (iii) to side scuttles fitted below a deck the underside of which at its lowest point was less than, or exactly, 7 ft. above the deepest subdivision loadline; (iv) to side scuttles which would not be accessible during navigation; (v) to side scuttles fitted in spaces intended for the accommodation of seamen or firemen; and (vi) to side scuttles in emigrant spaces. Side scuttles and their deadlights which would not be accessible during navigation were to be closed and secured before the ship left port. Side scuttles, other than those referred to in the above six classes, were to be provided either with hinged deadlights or fitted to receive efficient outer plugs, which would render the side scuttles practically watertight if the glass were broken.

Inlets and Discharges. The regulations were practically unaltered, but, as an alternative to the fitting of wrought steel boxes to the skin of the ship for the avoidance of long necks, chests having long necks were to be made of cast steel.

Scuppers and Sanitary Discharges. The control for a single automatic non-return valve at the outlet on the ship's side was to be operated from above the bulkhead deck. Where, as an alternative, two valves without control were fitted, the upper valve was to be situated above the deepest loadline and was to be accessible at all times under service conditions. Both valves were to be of automatic non-return type.

Ash Shoots, Rubbish Shoots, Etc. When the inboard ends of such shoots were situated below the margin line they were to be closed by efficient watertight covers, and, in addition, a horizontal balanced automatic non-return valve was to be fitted in the shoot in an accessible position above the loadline, capable of being secured in the closed position.

Bolts in Shell Plating. Bolts connecting cocks, valves, pipes, etc., to the shell plating were to have their heads outside, and the heads were to be either countersunk or cup-headed.

Double Bottoms. For large vessels the requirement as to the longitudinal extent remained unchanged, but that for determining the necessary degree of lateral protection was altered. (*See* Fig. 3.) The rule regarding the vertical extent in large ships was omitted. Wells for drainage purposes were not to extend downwards from the inner bottom more than 18 ins., nor were they to be less than 18 ins. from the shell or inner edge of the margin plate. At the after end of a shaft tunnel, however, a well extending to the shell was still permitted.

Watertight Decks. The prohibition of watertight decks below the level of the waterline was withdrawn. If a watertight deck were fitted above the loadline and extended through at least two main transverse compartments, the Board might make an allowance under certain circumstances in way of the watertight deck, but the 1915 rule regarding the definite increase in the factor of subdivision was omitted.

Longitudinal Subdivision. The rules regarding longitudinal bulkheads and inner skins were greatly modified. They were permitted, provided it could be shown (i) that if the wing compartments on one side were flooded for a length of ·05 L + 70 ft., or the length of the compartment through which the wing tanks extended, whichever was the less, the margin line would not be submerged; (ii) that the wing compartments were so sub-divided transversely that if two adjacent wing compartments on one side were flooded, the resultant list would not exceed 7°, or that if this list were exceeded approved arrangements were provided to speedily minimise it; (iii) the longitudinal bulkhead or inner skin was not less than ·02 B + 2 ft. from the shell of the ship.

When a transverse compartment was fitted with sub-divided wing or other compartments such as oil fuel bunkers, the crowns of which were not more than two-fifths of the moulded draught below the load line, and it could be shown that a blow which would open up the main compartment would leave some of the wing or other compartments intact and effective in contributing to buoyancy, the permissible length of the main compartment might be determined by means of an increased factor of subdivision, the rules for obtaining this being given in the Instructions. In the case of ships fitted with wing compartments extending continuously through at least two adjacent main compartments, the local factor of subdivision might be still further increased. A formula was included showing the increase when the crowns of the wing compartments were not less than one-fifth of the moulded draught above the load line. No allowance was to be made for tanks with crowns two-fifths or more of the moulded draught below the load line, and for intermediate positions the increase was to be obtained by interpolation.

Strength and Construction of Watertight Bulkheads, Decks, Tunnels, Trunks, Ventilators, etc. The scantlings of bulkhead plating and stiffeners with their attachments, and those of tunnel stiffeners, were slightly amended. In the case of large stiffeners the number of rivets in the attachment was reduced by one. There was little change in the remainder of the rules, but the clause requiring double-riveting of the boundary angles of bulkheads more than 24 ft. below the bulkhead deck was omitted, but where this distance exceeded 35 ft., the boundary angles were to be double-riveted in both flanges.

VI.—Supplement No. 2 (1932) to the 1928 Instructions.

This Supplement modified certain of the 1928 Instructions, the general effect being to make the subdivision a little more severe, though by no means so severe as that imposed by the 1915 Instructions. The principal modifications are indicated below, the remaining requirements of the 1928 Instructions still being in force.

Permeability.—Machinery Space. For steamships the average permeability $= 80 + 12{\cdot}5\left(\frac{a-c}{v}\right)$

where a = the volume of passenger and crew spaces situated below the margin line within the limits of the machinery space; c = the volume of 'tween deck spaces within the same limits appropriated to cargo,

coal or stores; and v = the whole volume of the machinery space. For motor ships the average permeability is to be 5 greater than as obtained by the above formula. This gives a more accurate estimate of the actual permeability than had been given by the method employed in the previous Instructions.

Factor of Subdivision. The curve of factors of subdivision for the "mixed" type remains as in 1928, but a new curve for the "passenger" type has been substituted. This gives a one-compartment standard for a ship having a length of 260 ft., as before, but two and three-compartment standards for lengths of 450 and 790 ft. respectively. (*See* Fig. 1.)

Criterion of Service Numeral. This is obtained from the same formulæ as in 1928, but the method of assessment of the value of P_1 is modified as follows: $P_1 = \cdot 6$ LN (L being the length of the ship in feet and N being the number of passengers for which the ship is certified). Where, however, it is shown that the value of ·6 LN is greater than the total volume of the passenger spaces above and below the margin line, and of the crew spaces below the margin line, the lower figure may be used, provided that the value of P_1 used is not less than ·4 LN.

In ships of any length carrying more than 12, but not more than 50, or $\frac{L^2}{7,000}$ passengers (whichever is the less), the subdivision abaft the fore peak shall be governed by the factor unity.

Limit of Length of Compartment. The upper limit of length of compartment is abolished, though the lower limit is maintained.

Steps in Bulkheads. A transverse bulkhead may be stepped, provided that the combined length of the two compartments, separated by the bulkhead in question does not exceed 90 per cent of the floodable length, or additional subdivision is provided in way of the step to maintain the same measure of safety as that secured by a plain bulkhead.

Stern-glands. A stern-gland is to be situated either within a watertight shaft-tunnel, or other space of such volume that if flooded by leakage the margin line will not be submerged.

Openings in Watertight Bulkheads and Watertight Doors. Sluice-valves in watertight bulkheads are no longer permitted. The old Class 5 watertight door (that with a releasing gear worked from the bridge) is omitted.

Side-scuttles. Any side-scuttles having sills below a line drawn parallel to the bulkhead deck, and having its lowest point ·025 B above the load line, shall be of a non-opening type. If, in a 'tween deck, the sills of all the side-scuttles are higher than the above line, but not all above a line drawn parallel to and 12 ft. above it, they shall be either of the non-opening type or of such construction that they cannot be opened without the consent of the master. Other side-scuttles may be of the ordinary opening type. Rules are given indicating which side-lights must be closed and locked before the ship's departure.

The rules regarding the six classes of sidelights, to which hinged inside deadlights are to be provided, remain very much as in 1928, but for those in class (iii), viz., those situated below a deck having its lowest point less than or exactly 7 ft. above the loadline, have been substituted all side scuttles situated in a 'tween decks where the sills of any are situated between a line drawn parallel to the bulkhead deck and having its lowest point ·025 B above the load line, and another line drawn 12 ft. above the first. All other side scuttles not included in the six classes named, but situated below the bulkhead deck may be fitted with portable plugs instead of deadlights.

Circular 1485 (under-water pattern sidelights) still applies to side scuttles having sills less than 6 ins. above the loadline.

Longitudinal Subdivision. The angle of heel of 7°, due to the flooding of wing compartments, is to be considered in relation to a flooded length of ·02 L. + 10 ft.

Allowance for Local Subdivision. The complicated rule of 1928 is simplified. Where a main transverse compartment contains local subdivision, and it can be shown that, after any assumed side damage extending over a length in feet of ·02 L + 10, the whole volume of the main compartment will not be flooded, a proportionate allowance may be made in the permissible length otherwise required for such a compartment. In such a case, the volume of effective buoyancy assumed on the undamaged side shall not be greater than that assumed on the damaged side.

VII.—Conclusion.

A comparison of the curves of Factor of Subdivision, indicated in Fig. 1, reveals that the curve of 1915 for all types of vessel meets the "passenger" curve of 1928 at a point representing a ship having a length of 700 ft., and the two curves yield ordinates of practically equal value for lengths of ship beyond 700. Thus a vessel of 700 ft. in length carrying only 13 passengers (if such a vessel can be imagined) would, by the 1915 Instructions, have required the same standard of subdivision as that required by a ship of the same length carrying several thousand passengers, after the coming into force of the 1928 Instructions.

Whether the relaxation permitted by the 1928 and 1932 regulations is justified cannot be stated, as fortunately there has not been a disaster, such as those which overwhelmed the Titanic and the Empress of Ireland, to a large passenger ship built in conformity with these regulations.

By way of practical illustration as to the effect of the alterations in the subdivision regulations two typical vessels have been chosen, one being of the "mixed" type and the other of the "passenger" type. As the position of bulkheads depends not only on compliance with subdivision regulations but also on the necessities of design (machinery spaces, fuel tanks, deep tanks, etc.), instead of investigating the number and spacing of bulkheads which would be required for a given draught, the maximum moulded draughts, permissible under the different regulations, which correspond to the actual arrangement of bulkheads, suitable for the service of the vessels, have been determined.

The "mixed" type ship has the following dimensions:—Length, B.P. 475·0 ft. Breadth moulded, 58·0 ft. Depth to margin line, 34·0 ft. Number of passengers, 234.

A profile of the ship, together with the curves of floodable and permissible length, is indicated in Fig. 4.

The comparative results of the subdivision investigation are tabulated below:—

Regulations.	1915 Instructions.	1928 Instructions.	1932 Supplement No. 2.
Block coefficient	·762	·77	·77
Freeboard ratio...	·337	·233	·236
Sheer ratio, forward	·433	·399	·40
Sheer ratio, aft	·216	·199	·20
Permeability, after body ...	64·65	63·0	63·0
Permeability, machinery space...	80·00	75·0	77·9
Permeability, forward body ...	62·96	63·0	63·0
Criterion of Service Numeral ...	—	26·0	26·0
Factor of subdivision	·678	·856	·854
Maximum permissible draught...	25 ft. 5 ins.	27 ft. 7 ins.	27 ft. 6 ins.

The permissible draughts under the 1928 and 1932 regulations are respectively 8·5 and 8·2 per cent. greater than that permitted by the 1915 Instructions. The difference, of course, is chiefly due to the difference in the factors of subdivision. The permeability in the machinery space varies considerably, due to there being a 'tween deck below the margin line used for coal, but not for passengers or crew. This produces a variation in the floodable length and permissible length curves in way of the machinery space, and, if reference is made to Fig. 4, it will be seen that the intermediate bulkhead required in that space by the 1915 and 1932 curves is not required by the 1928 curve.

Fig. 5 illustrates the manner in which the same ship might have been sub-divided under the Board of Trade Circular No. 1623 of 1920, in relation to a moulded draught of 25 ft. 5 ins. The factor of sub-division for all the compartments abaft No. 2 hold is ·883, while the fore peak and No. 1 hold taken

together comply with a factor of ·90, as do Nos. 1 and 2 holds taken together. As a result, with the exception of the two forward holds, the remainder are very spacious. As a matter of interest, it may be noted that the number of bulkheads required to comply with the above Circular for this ship, viz., seven, is one less than that required by the Rules of this Society.

The vessel of "passenger" type has the following particulars: length B.P. 730·0 ft., breadth moulded 97·5 ft., depth to margin line 45·0 ft., number of passengers 1213. A profile of the ship and the curves of floodable and permissible length are indicated in Fig. 6.

This case has been investigated by comparing the combined lengths of every pair of adjacent compartments in the ship, with a curve of which the ordinate at any point is equal to twice the permissible length of one compartment at that point.

The comparative results of the investigation are tabulated below.

Regulations.	1915 Instructions.	1928 Instructions.	1932 Supplement No. 2.
Block coefficient	·626	·64	·638
Freeboard ratio	·389	·279	·295
Sheer ratio, forward	·347	·318	·322
Sheer ratio, aft	·149	·136	·138
Permeability, after body ...	79·8	76·6	76·6
Permeability, machinery space...	80·0	76·5	81·5
Permeability, forward body ...	72·0	72·2	72·2
Criterion of Service Numeral ...	—	75·35	75·35
Factor of subdivision	·376	·455	·439
Maximum permissible draught...	32 ft. 3 ins.	35 ft. 2 ins.	34 ft. 9 ins.

The permissible draughts under the 1928 and 1932 regulations are respectively 9·0 and 7·7 per cent greater than that permitted by the 1915 Instructions.

The greater permeability of the after body, under the 1915 Instructions, is due largely to the fact that part of the shaft tunnels had to be taken as having a permeability of 95 per cent under those regulations.

The remarkable figures are those for the factors of subdivision under the 1928 and 1932 Regulations. Although the number of passengers assumed to be carried in this case is about the average carried by a first-class modern liner of this length, the factors of subdivision, viz., ·455 and ·439, are greater by 21 per cent. and 17 per cent. respectively, than that permitted by the 1915 Instructions for a vessel of the same length, and it will be remembered that the 1915 curve was that recommended by the Bulkhead Committee of 1912 for vessels of the "mixed" type.

Another notable figure is that for the Criterion of Service Numeral 75·35. A reference to the 1928 and 1932 Regulations will show that the Criterion of Service Numeral corresponding to the full "passenger" type is 123. A ship of the length under consideration, viz., 730 ft., having the passenger spaces below the margin line shown in Fig. 6, would require to carry no less than 12,960 passengers before her Criterion of Service Numeral would reach 123. This figure is quoted to show the impossible intensity of passenger loading contemplated by the "passenger" curve of factors of subdivision, as compared with actual present-day passenger figures.

The factor of subdivision under the 1915 Instructions, viz., ·376, is smaller than the "passenger" factor under the 1928 Instructions, viz., ·380, and under the 1932 Regulations would be required by a Criterion of Service Numeral of 109, which would represent a passenger capacity of no less than 6,190.

If the preceding account of the recent developments in the subdivision of large passenger liners provokes thought and discussion in the members of this Association, its purpose will have been fulfilled.

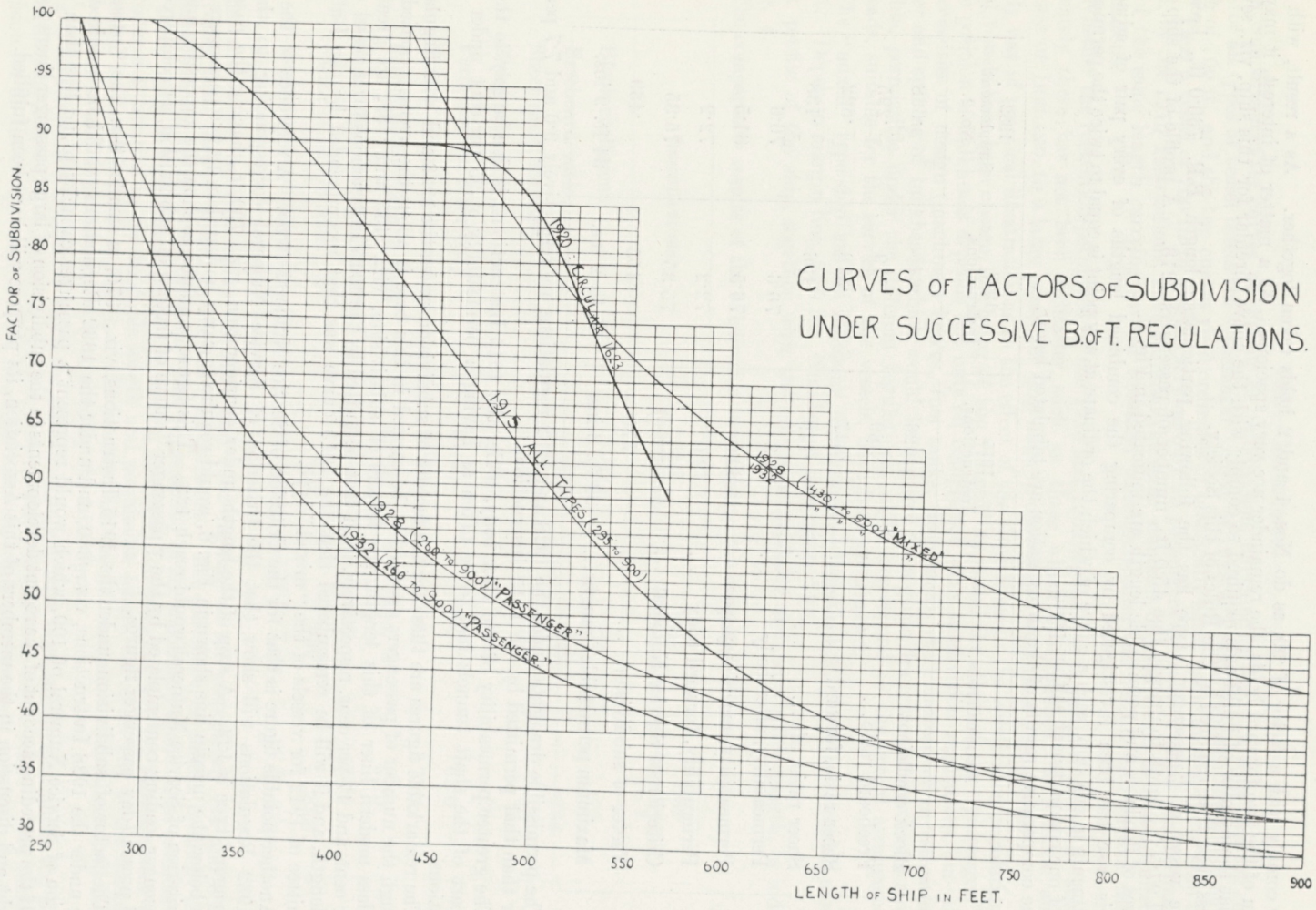

CURVES OF FACTORS OF SUBDIVISION
UNDER SUCCESSIVE B. OF T. REGULATIONS.
FACTOR OF SUBDIVISION.
LENGTH OF SHIP IN FEET.
1·00
·95
90
85
·80
·75
70
65
60
55
50
45
·40
·35
30
250
300
350
400
450
500
550
600
650
700
750
800
850
900
1920 CIRCULAR 1623
1915 ALL TYPES (295 TO 900)
1928 (260 TO 900) "PASSENGER"
1932 (260 TO 900) "PASSENGER"
1928 (430 TO 800) "MIXED"
1932 " " " "

FIG. 1.

Fig. 2: Recesses

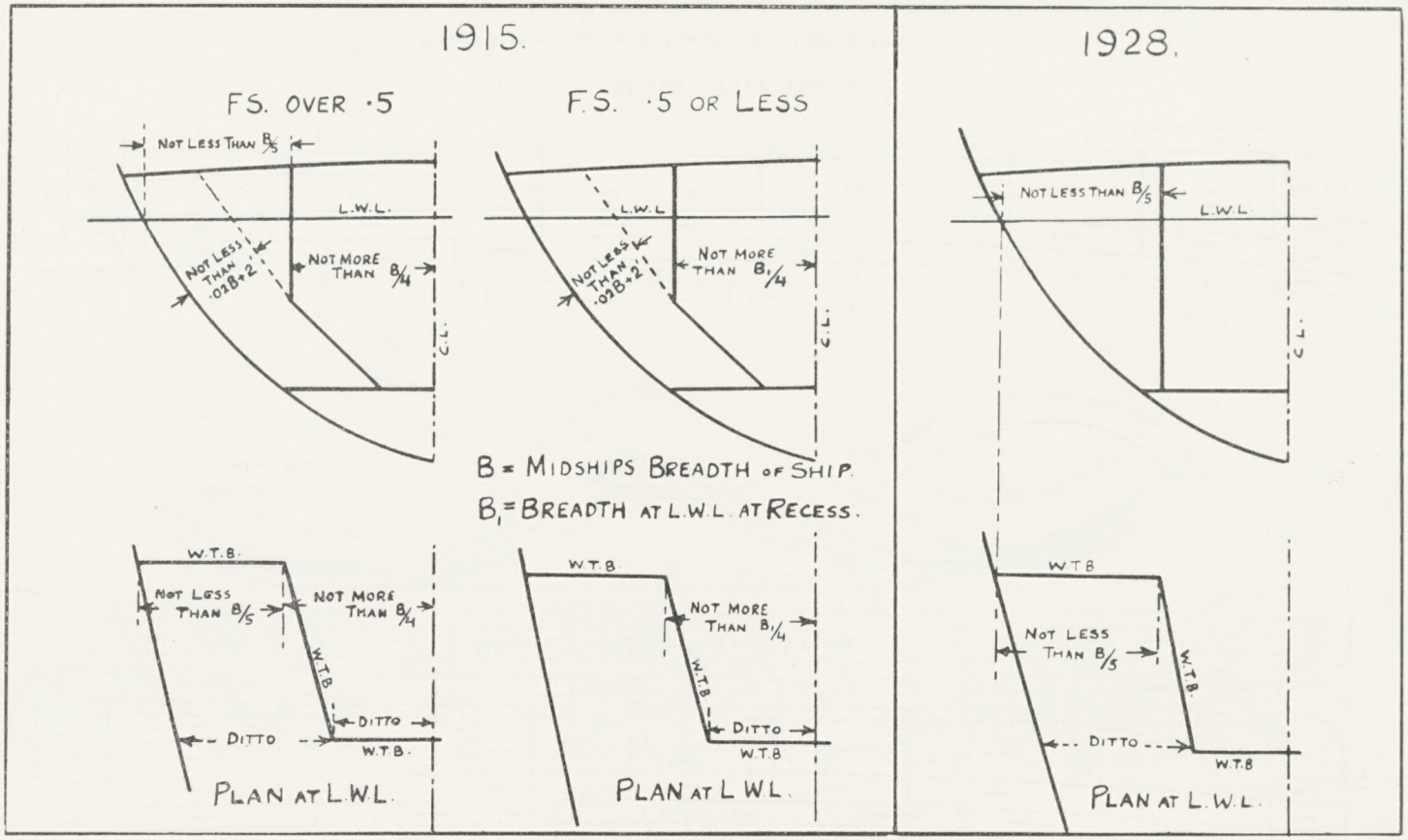
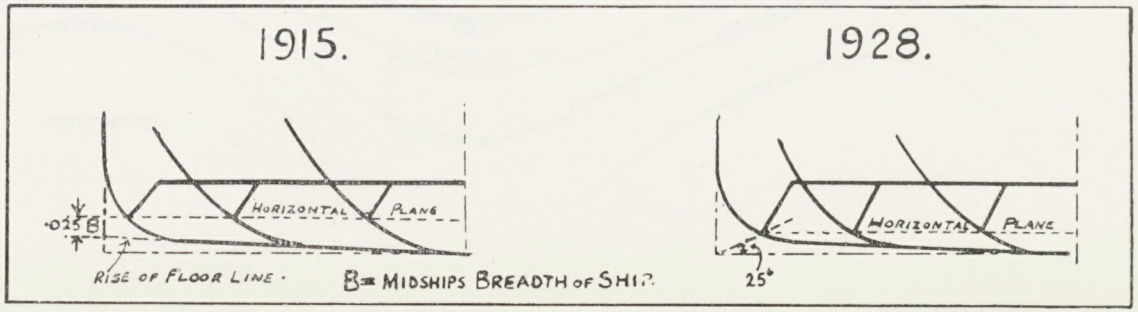


Fig. 3: Double-Bottoms



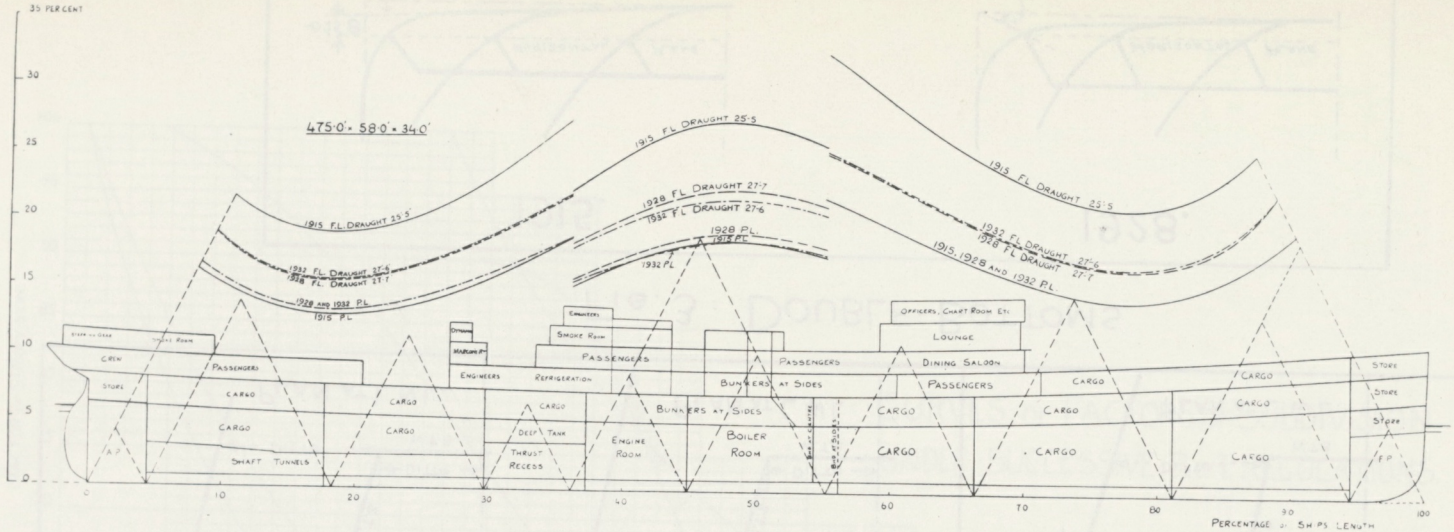


FIG. 4. "MIXED" TYPE VESSEL.

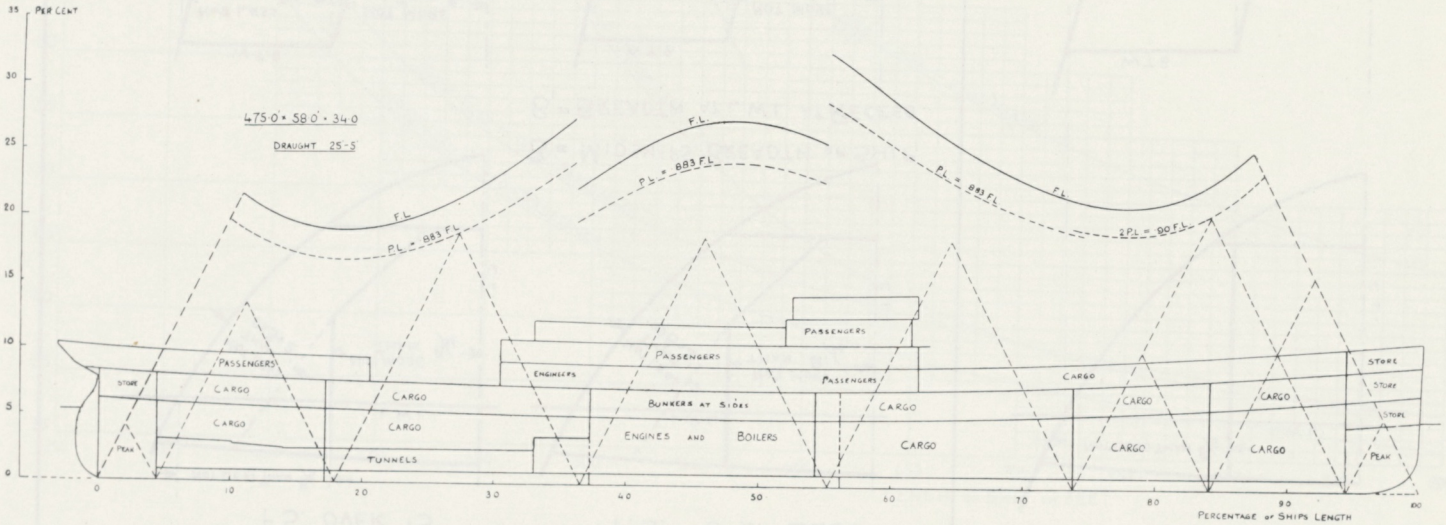


FIG. 5. "MIXED" TYPE VESSEL.

Subdivision according to Circular No. 1623 of 1920.

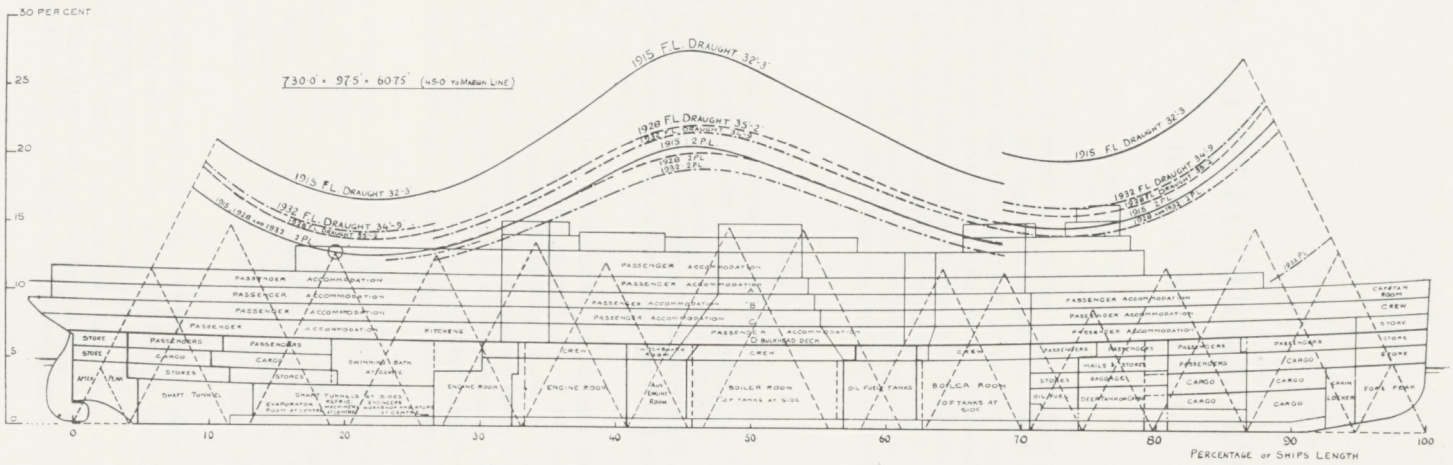


FIG. 6. "PASSENGER" TYPE VESSEL.

PART II.—(c) ELECTRICAL EQUIPMENT.

By G. O. WATSON.

Fortunately, the term "recent" is elastic and lacks mathematical precision, so that we may stretch our review back over a number of years, for had a limit been set, say five years back, it would have been well nigh impossible to point to any one development as having originated within that period. For "development" in the electrical equipment of passenger vessels has been rather in the direction of steady improvement in the quality of materials, workmanship and methods, and the more extended use and perfection of developments which started a decade or more ago. It is, therefore, proposed to deal with the general trend and to describe briefly some of the features which are now found in the majority of new vessels, and it will be convenient to deal with these under separate headings.

Cables.

It is appropriate that we should commence with cables for they are perhaps the most vital part of the equipment and the source of most worries. It is consoling to know, therefore, that considerable progress has been made in improving the quality of the insulation on cables. Rubber is still the material most commonly used and research is continually in progress to improve the product. Although an excellent material in many respects, rubber suffers from the disadvantage that it deteriorates with age, this deterioration being due to oxidation.

A further disadvantage, which is now eliminated by modern methods, was the presence of free sulphur not absorbed by the rubber during the process of vulcanisation. In the past approximately 8 per cent of sulphur was added for vulcanisation, approximately 2 to 3 per cent of this being absorbed and the remainder being free. It was to protect the conductor from this free sulphur that specifications called for a layer of pure rubber to be applied next to the conductor and also as a further protection the copper was tinned. This proved fallacious, for the sulphur migrated through the pure rubber and eventually reached the conductor. Moisture travelling up the strands combined to form sulphuric acid with dire results.

Modern rubber has only about 2 to 3 per cent. of sulphur included in the initial mixture, and only a mere trace of free sulphur is present after vulcanisation. In fact, some rubbers are claimed to be sulphurless, though the validity of this is open to doubt. The primary reason for the layer of pure rubber no longer holds and many cables are now produced without it, though some manufacturers retain it in order to improve the insulation resistance. The efficient tinning of the conductor is still necessary and important, and it is probable that a chemical test to prove its efficiency may be added to the requirements.

As already mentioned, the other drawback with rubber is its proneness to oxidation. It deteriorates from exposure to air and sunlight, ozone being particularly harmful, and it is for this reason that cables are lead sheathed. Lead sheathing, however, particularly on board ship, still leaves much to be desired. Pure lead is very largely used and many early specifications were at great pains to specify pure lead. Research has shown, however, that pure lead cracks very readily when subject to continual vibration such as exists on ships, and certain alloys of lead are more resistant to vibration cracking. They are as follows:—

Alloy.	Composition (Percentages).				Fatigue Limit. *Tons/sq. in.	Situation for which Alloy is suitable.
	Lead.†	Tin.	Antimony.	Cadmium.		
Lead	100	—	—	—	± 0·18	Where no vibration.
A	98	2	—	—	± 0·40	Ship wiring. Preferable to other alloys where organic acid corrosion occurs.
B	99·1	—	·9	—	± 0·60	Ship wiring, but is rather stiffer than Alloys A or C.
C	99·45	·4	—	·15	± 0·35	Ship wiring, where vibration resistance combined with flexibility for installation purposes is necessary.
D	99·25	—	·5	·25	± 0·74	For positions where a higher resistance to vibration is required.

* Taken as range of stress which will cause failure after 10 million reversals.
† Including impurities of zinc and bismuth.

Lead sheathing also corrodes very rapidly, this failure being largely due to electrolytic and galvanic action, in association with neighbouring steel and brass. To arrest and restrict corrosion it is necessary to bond the parts together, this being a requirement of the Rules, and much of the deterioration which is frequently found is due to the requirement not being efficiently carried out.

The bonding to earth introduces another factor, viz., the presence of earthed metal in intimate contact with the dielectric throughout the run of the cable, so that any failure of the insulation immediately shows up as an earth. The failure may be a natural one due to ageing or the working of the ship, or on the other hand may be due to a workman driving a nail through the cable. This instantaneous indication of a fault may, on the one hand, be considered advantageous, or on the other hand, is by some considered a drawback.

Nevertheless there is a growing tendency to get away from lead sheathing and to use what has grown to be known as "H. R." sheathing.

"H. R." is purely a trade designation and does not, as is commonly supposed, mean "hard rubber," the latter being vulcanite or ebonite, which are totally unsuited for the purpose.

"H. R." is a secret composition produced by several manufacturers, who will not disclose its contents, but which usually includes from 5 to 10 per cent of bitumen. Its main attributes are that it is oil resisting and has good mechanical qualities, and, while protecting the dielectric, does not suffer from the disadvantages of lead.

A number of makers have submitted samples to very stringent tests, and as a result the Committee has approved their use in lieu of lead sheathed cables. The growing use of this type of cable, which was first introduced about the year 1928, must, therefore, be definitely logged as a recent development.

Another type of cable, the use of which commenced about the same time, is the varnished cambric insulated type. The dielectric consists, as the name infers, of cambric which has been impregnated with varnish, which may be either a bitumen or a linseed oil varnish. The former is black in colour while the latter in usually yellow or amber, sometimes known as "Empire cloth," but is sometimes artificially coloured black.

These distinctions are important, as the linseed oil or "yellow" varnished cambric should not be used in direct contact with bare copper owing to a chemical action which is set up. It is, therefore, necessary either to tin the conductors or insert a layer of treated paper or other separator next to the conductor. The yellow variety has better insulating qualities than the black and is therefore preferred.

The cambric is merely a vehicle, having very poor insulating properties, the latter depending entirely on the efficiency of the varnish. The cloth is made up in rolls, approximately 30 to 40 ins. in width and is cut into tapes from $\frac{1}{2}$ in. to $1\frac{1}{2}$ ins. wide before being wrapped round the conductor. When it is cut, the cambric threads are exposed at the edges of the tape and consequently if left exposed to the atmosphere, moisture would travel up each of these threads and destroy the insulating properties.

All varnished cambric insulated cables are, therefore, required to be lead sheathed in order to exclude moisture, and for the same reason the ends of each cable are required to be sealed. Incidentally, it is excellent practice also to seal the ends of rubber insulated cables to prevent moisture creeping up the strands, moisture being the most prevalent cause of electrical breakdown.

Varnished cambric will withstand higher temperatures than rubber and, therefore, a smaller section of copper conductor is permissible for a given current than for rubber insulated cable. For this reason varnished cambric cables for the heavy distribution circuits are growing in favour. It is not generally used for the more numerous small cables owing to the expense of sealing the ends.

More attention is now being paid to the fixing and positioning of cables. Instead of cables being laid in loose bundles behind partitions, they are now cleated in position on perforated steel trays or direct on bulkhead. The former method should never be tolerated and undoubtedly constituted a grave fire hazard.

Selective Tripping.

This is perhaps the most important and, at the same time, most recent development in electrical distribution, and first came to the fore about 1929.

The electrical load in passenger vessels when at sea is of a somewhat diverse character, comprising some services which are of a vital and essential character such as steering gear, navigation lights, engine room auxiliaries and others which are not so vital. The former are more or less constant in character and under the direct control of the engineers. The "hotel" load as it is called, comprising electric galleys, accommodation heating, lighting, fans, lifts, cinemas, etc., is subject to fluctuations, and is not under the immediate control of the engineers.

Consequently, if all these services are connected to the same busbars there is a danger of the load being increased beyond the capacity of the generators in service for the time being. This would result in the circuit breakers opening on overload and cutting off the essential and vital services as well as the hotel load or non-essential services.

The practice has therefore been established of providing what is known as "Selective Tripping." Certain circuits, known as "Preferential Circuits" are selected, and in the event of overload the "non-preference" circuits are tripped out first. In large vessels the circuits are sometimes further sub-divided into "First preference" and "Second preference."

The non-preference circuits are usually tripped out instantly, without time lag, as soon as the overload occurs, while the preference circuits are provided with a time lag which can be varied and usually has two settings, viz., 5 seconds and 10 seconds. If after the non-preference load has been relieved the overload still persists, the "second preference" circuits will be cut off at the end of 5 seconds, and after 10 seconds the "first preference" will be cut off.

In practice there are several methods of carrying out these operations.

Navigation.

Not least in importance is the immense advance which has been made in aids to navigation, such as Wireless Telegraphy, Depth Sounding, Direction Finding, Gyroscopic Compass and Automatic Steering. By means of time signals received by wireless the navigator is no longer solely dependent on his chronometer for G.M.T.

Depth Sounding is based in principle on the rate of travel of sound in water and is dependent on electrical methods to record accurately the time taken for signals to reach the ocean bed and return to the ship. The older method of lead-line or plummet was slow and cumbersome, the ship having to be slowed down or stopped and needing the services of several members of the crew. Then when the reading was obtained it represented the depth taken several minutes previously and, if the ship is still on the move, the depth some distance away.

Echo Sounding is based on the fact that sound travels in water at a uniform rate of approximately 4,900 ft. per second, and the time taken in seconds for sound to travel from the hull to the sea-bottom and echo back to the hull multiplied by 4,900 and divided by two, represents the depth in feet. Deep sea craft are usually fitted with echo-sounding apparatus which will indicate a minimum of five to six fathoms from the bottom of the hull but more sensitive apparatus, recording down to two fathoms, can be supplied and is normally fitted to coastwise trading vessels.

Recording charts can be fitted, on which a pen draws a line at stated intervals of upwards of twenty soundings per minute, the length of the line indicating the depth of the sea. The succession of lines of varying length results in a chart indicating in profile form the shape of the sea bottom. It is also possible to determine the nature of the sea bottom, i.e., whether hard or soft.

The time taken to make soundings is normally under one second and, on account of this rapidity of operation, soundings can be taken when the vessel is proceeding at full speed with the same degree of accuracy as when stationary. A sudden change of, say 120 fathoms to 3 fathoms, will be instantly recorded.

Although the various makes on the market vary considerably, in the sending and recording apparatus the fundamental principles remain the same, and the apparatus is in three sections, viz., a transmitter or "hammer" to produce the sound, a hydrophone or receiver to pick up the echo, and the instrument or meter to indicate to the navigator in the wheel house or chart room the results obtained.

In some makes the transmitter and receiver are combined in the same fitting, thus requiring only one attachment to the hull. This type makes use of supersonic waves, i.e., waves of higher frequency than can be detected by the human ear. In other types the transmitter and echo receiver are separate and about 40 to 50 ft. apart. All types are sensitive to air bubbles passing under the hull and across the faces of the transmitters and receivers, and great care has to be exercised in selecting positions free from this form of disturbance. The supersonic types are more subject to errors from this source than those dependent on sonic waves.

Although the recording is done with the aid of a dry cell of 4 or 5 volts, this may be amplified to 2,000 or 3,000 volts in the transmitting circuit in the supersonic system, and for this reason special precautions are necessary when these circuits are in the vicinity of oil tanks containing low flash point oil.

Storage Batteries.

Although the use of secondary batteries for emergency purposes is not universal, nevertheless it is fitted in many cases, and considerable advance has been made in the efficiency and mechanical construction of batteries.

In the early days of electricity on board ships the only batteries available were of the open tank type, quite unsuitable for use on ships. The development of the submarine and motor car types of battery have no doubt been responsible in no small measure for the more serviceable batteries now available. Batteries are now practically totally enclosed with comparatively small holes for breathing purposes, and will withstand the rolling action without any risk of spilling the electrolyte.

For supplying emergency lighting in engine rooms, etc., a system, known as the "Keepalite" system, has been developed. With emergency or "panic" batteries, a problem in maintenance arises in regard to the necessity for keeping the batteries fully charged and in good condition. A system has now been developed for keeping a very small "trickle" charge on the battery day and night to prevent loss of charge and deterioration on open circuit. In the event of failure of the normal supply from the ship's generators, a change-over contactor switch automatically comes into action to maintain a supply to certain selected "panic" lights.

Hotel Services.

These may be divided broadly into two categories :—

(1) Services in public rooms, cabins, and accommodation generally.

(2) Services in the kitchens, galleys, laundries, ironing rooms, etc.

In the first-mentioned category we find that the lighting of dining saloons, lounges, ballrooms and drawing rooms is on the same elaborate scale as the most modern of first class hotels. Ornate and concealed lighting, employing thousands of lamps, is the order of the day. In some of the larger liners as much as 125 kw. is used for the lighting of a single room.

A 20,000 ton passenger liner will have as many as 6,000 switches and lighting fittings, and 20,000 electric lamps.

Cabins are invariably provided with electric fans and radiators, and a ship of this size will have 600 to 700 fans and as many radiators.

Ballrooms are frequently fitted with colour lighting which can be varied and dimmed from a central control position, and in at least one liner now building, a system of thyratron control is to be fitted, in which the band music controls the lighting.

In this system the music is picked up by a microphone, the current in which passes through amplifiers and is then used to control the grid voltage of a thyratron valve. This in turn reacts on a special type of choke having an A.C. and a D.C. winding, and the volume of lighting is thereby controlled. Three colours, blue, red and green are employed, one being predominant when low notes are rendered, and another responding to high notes.

Cinema equipments are also fitted in the majority of modern liners.

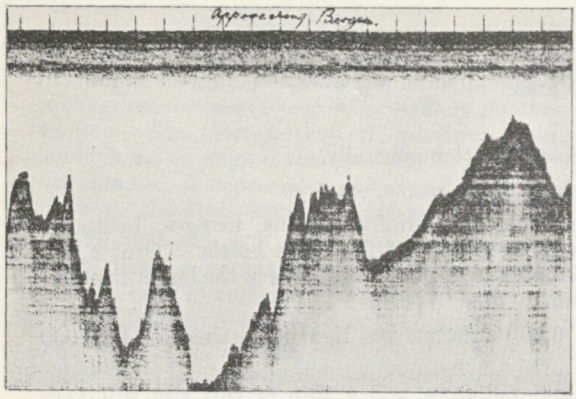
Telephones are fitted in all passenger liners, and in the case of luxury ships the installation is extended to the cabins ; in one instance a telephone board of 450 lines was used for this purpose.

For internal communications between individual cabins and stewards, it is now customary to have an indicator located outside each cabin, and a "group" indicator for the steward. The local indicator on the cabin may consist of a "flag" which drops into view or a luminous signal which lights up when a call is made. These signals remain until the steward enters the cabin and cancels or resets them by pressing a button in the cabin.

" Below stairs " electrically operated galleys are becoming increasingly popular. Electricity is used for ranges, hot cupboards, fish friers, water boilers and urns, hot plates and carving tables. Also potato peelers, "iron cows," egg boilers, which automatically remove the egg after a given time, dish washing machines, etc. In the laundry there are electrically driven washing and ironing machines, mangles and electric irons.

In some instances rooms are set aside where passengers can do their own ironing. This is an attempt to deal with the evil of passengers who bring their own electric irons, often unsuited to the supply voltage of the ships. For instance, in U.S.A., the supply to buildings for lighting purposes is 110 volts. whereas most ships are 220 volts.

In conclusion, the author wishes to thank Messrs. Henry Hughes & Son, Ltd., for the loan of blocks.



Typical Recording Chart of an Ocean Bed.

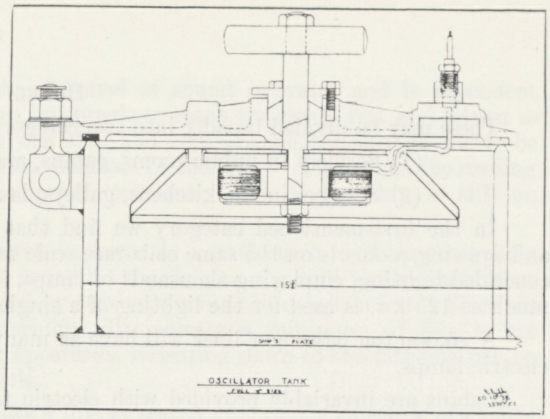
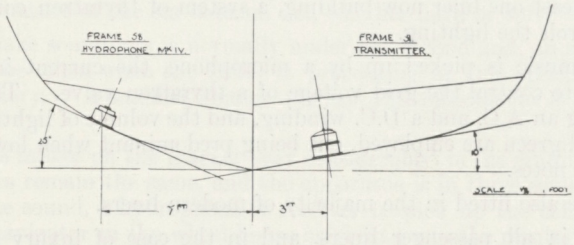


Illustration of the Oscillator.



Athwartship Arrangement of Transmitter and Receiver.

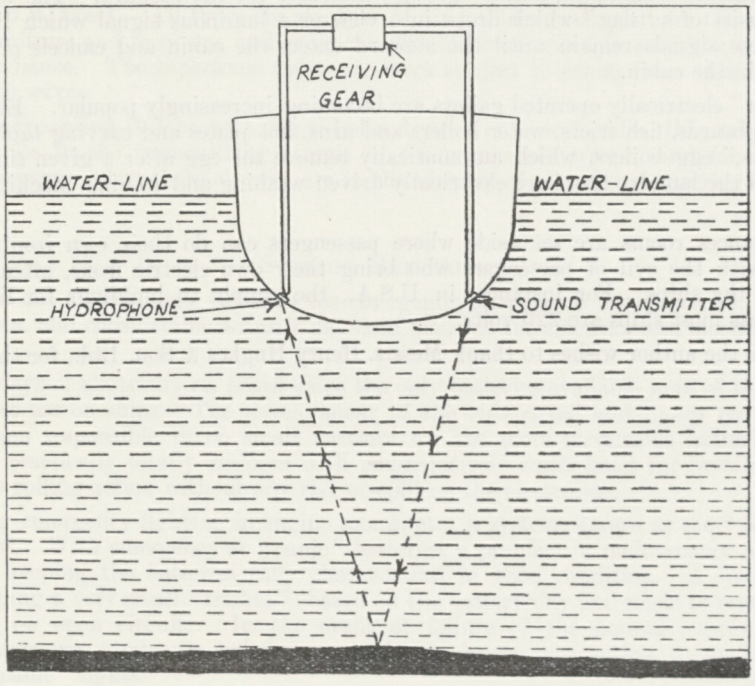
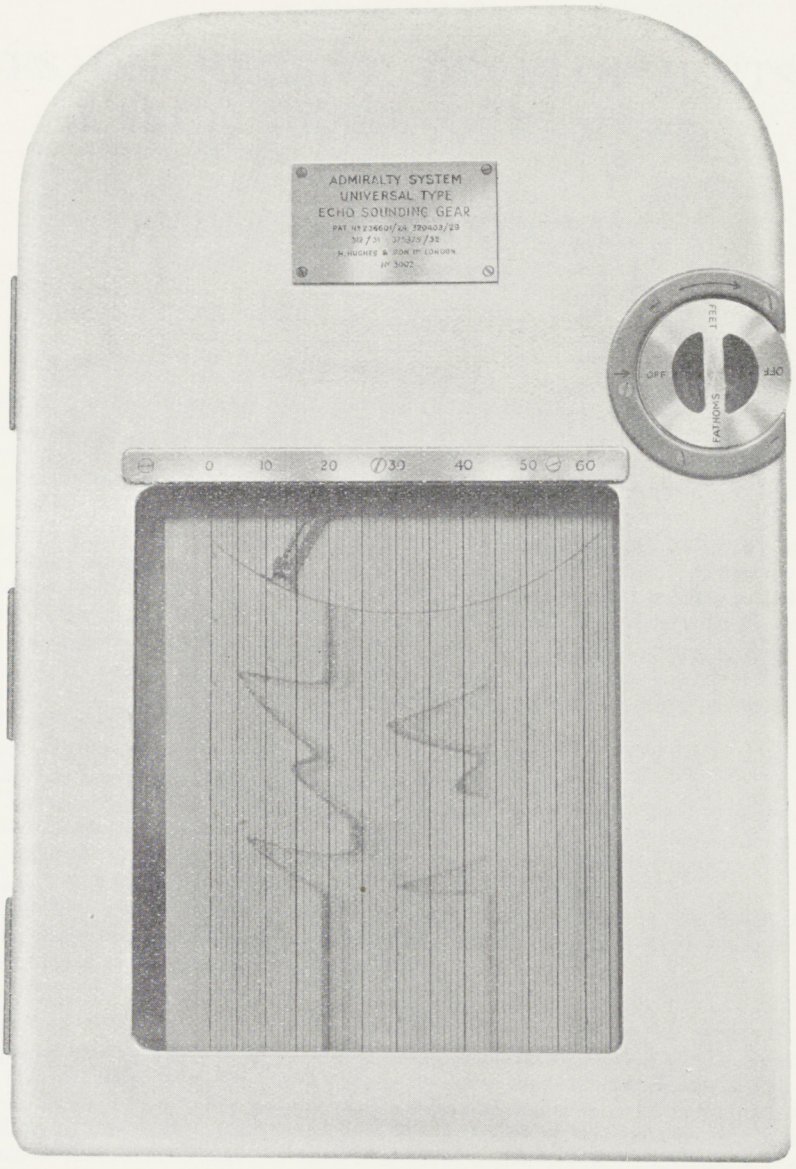


Illustration of the Principle of Echo-sounding.



Rotating Arm Curved Scale Recorder. Readings are obtained within 3 feet of the Ship's Bottom.

DISCUSSION ON

NOTES ON RECENT DEVELOPMENTS IN LARGE PASSENGER SHIPS.

PART I.—(a) STRUCTURAL.

By S. TOWNSHEND.

E. W. Blocksidge.

It is my own personal opinion that we have reached the maximum limit in regard to the size and length of large passenger ships, after careful consideration of the main essential relations to the facilities and depth of water provided at terminal ports, cost of upkeep and the provision of an adequate equipment of life saving appliances in order to carry a reasonable number of passengers which will recompense the shipowner.

We shall have to wait and see whether the financial returns are sufficient to justify such a colossal outlay as was necessary to construct the "Queen Mary" and "Normandie," having in view that the cost was four times as great as that spent on the "Aquitania," and with a reduction in the number of passengers carried, but with an increase in the number of crew, when compared with the latter ship.

The modern demand for luxury accommodation for passengers is not confined to large ships engaged in the North Atlantic Service. The facilities which are now provided on modern ships for the comfort of the passenger have directly affected the numbers which can be carried, which indirectly increases the standard of safety and efficiently.

It is interesting to note in recent papers given before the Members of the North East Coast Institution of Engineers and Shipbuilders, it was stated that the machinery of the "Bremen" is 120,000 S.H.P., and its weight 7,763 tons, with a consumption of ·685 lbs. of oil per shaft horse power per hour. The builders have stated that, with modern boilers of 900 lbs. pressure, an installation of 180,000 S.H.P. could be fitted with a weight of 7,280 tons and a consumption of ·575 lbs. per S.H.P. hour. This installation would occupy 17½ per cent less length than the present machinery fitted.

I suggest, therefore, the development of the modern passenger ship in the future will be in the direction of smaller dimensions, embodying machinery of lighter weight and a reduction in space with an increase in speed, number of passengers carried and cargo capacity.

W. Thomson.

The first paper of this symposium deals with the very important question of the scantlings of large passenger vessels and Mr. Townshend has set forth clearly the general considerations which govern these. As pointed out by him, these vessels have been designed in different countries and embody the ideas of various naval architects, a fact which makes the problem of analysing the scantlings somewhat difficult. In addition it must be remembered that the number of such vessels is small and from a consideration of the evidence available I would suggest that the results of such analyses are really irreconcilable. It is known that in a few cases the structure has proved to be not very satisfactory, which at least provides a starting point for investigation but whether in other cases the scantlings are too heavy cannot be known, for which reason it would appear that the suggestion in the paper that the calculated stress should vary as $\sqrt[3]{L}$ is a refinement which is hardly justified at this stage.

Mr. Balfour's investigation two years ago proposed a relationship between depth of structure and draught as affecting scantlings, but here again the lack of definite knowledge militated against the acceptance of his conclusions.

The tendency to fit divided uptakes raises the question, dealt with by the author, as to the value to be assigned to the deck plating between the openings and his conclusions will be generally accepted. The top and bottom flanges of a girder can only be regarded as acting together when joined by an efficient web. In the case of a ship this web is provided by the side shell plating, and the deck plating between the uptakes, being quite divorced from the side shell, can have only a limited value in resisting longitudinal stress, but the actual part played by this material must remain a matter of opinion.

In dealing with the question of vibration the author strikes the right note in relation to the scantlings of the beams and girders of decks of superstructures. There can be no doubt these must be appreciably heavier than if based on purely static considerations.

W. Bennett (New York).

Mr. Townshend has covered the subject so well that there is not much one can add by way of remarks, except to thank him for bringing us up-to-date on this interesting topic.

The greatest developments in large passenger ships are, undoubtedly, passenger comfort and speed. In years gone by passenger accommodation was far from what could be desired, and the attitude of the shipowner of those days was, more or less, "take it or leave it." To-day the passenger is more travel conscious, and goes shopping around different lines to get the best value for his money. With the strenuous competition now prevailing, it influences the shipowner to offer the passenger every modern means of comfort, and in some cases, luxury, so as to induce him to travel on his line.

Take for instance, one well-known line sailing out of New York; their vessels to a large extent sell themselves to the public owing to the superior accommodations and the outstanding innovation which is not prevalent on many ships, viz., that each and every room throughout their vessels have a bath (or shower) and toilet. In addition to this the rooms are attractive, games are arranged for the passengers' entertainment, movies are shown, an orchestra is provided for dancing, and an outdoor pool for swimming, so that every whim of the average traveller on the high seas is catered for, and they get more value for their money to-day than they ever did before.

Under the heading "Progress in General Design and Appearance," attention is directed to the great change in appearance. My own impression is that much that goes down under the caption of streamlining is really overdone, in much the same manner as the super-streamlined motor-cars which appeared in the U.S. several years ago, simply pandering to the distorted æsthetic tastes of an extremely sophisticated motoring public. Their utility, in so far as the streamlining is concerned, was not proven by experience, and now a more sensible and less modernistic design is in vogue. The "Queen Mary" is, I believe, much more conservative in her general design and appearance, and will, I am sure, be none the less successful in spite of these.

In regard to "Accommodation," I would suggest one important omission, in that the greatest change which has developed recently in the accommodations of large Atlantic liners is the attention given to cabin and tourist passengers which, of course, is the old second and third class camouflaged and served up under a new "sales-tag." There is a tendency to increase the number of one and two berth rooms, with correspondingly more toilets and bathrooms.

I read recently, although I am uncertain as to its accuracy, that a new ship was recently commenced in which the few passengers carried will be accommodated in the dummy funnels, which shows just how incongruous, in a motorship, the modern funnel really is.

Another feature of some interest is the arrangement of rooms in the "Manhattan" and "Washington," by which some of the cabins on the "A" deck are arranged in pairs, outside and inside; the outer being the sitting room and the inner the bedroom, with a glass curtained partition between, providing light to both.

In his conclusion, Mr. Townshend refers to the damage possible to large Atlantic liners due to shipping heavy seas on deck. I remember several such instances of severe damage, but one will suffice. The "Majestic," until recently the largest vessel on the Atlantic, took, a few years ago, a very heavy sea over the bow. It broke on No. 2 hatch, which was steel covered with heavy stiffening underneath, stove the hatch cover down, and a following sea broke on the same spot, killed a sailor, washed out much of the third class accommodations, broke pillars, and flooded the hold damaging much valuable cargo.

I am, as one would expect, in more intimate contact with transatlantic vessels than any others, but I have spoken to many Masters who have sailed the seven seas, and they are all unanimous that the

Atlantic crossing can be the most hazardous of them all. The importance, therefore, of providing means of preventing seas from breaking on the fore deck cannot be overemphasized, and also for the freeing of any water which may break on the deck.

It is difficult to visualize the possible trend in the development of large liners of the future. That there will be development goes without saying, but there must be an economic limit, if not a practical limit to the development of such vessels in respect of size, speed and lavish decorations. These luxuries and, in some cases, extravagances, have to be paid for, and they must be reflected in the cost of the passage to the individual; and when it comes down to the average traveller, one will probably find that they are looking for a safe, comfortable ship, of moderate speed, at as reasonable a fare as possible.

Who, for example, wants to travel in a floating art gallery? It is safe to predict, therefore, that the popular ships of the future will be of the intermediate type such as the "GEORGIC," "BRITANNIC," "MANHATTAN" and "WASHINGTON," rather than those of the super-liner type; and that the tendency in future development will be along the intermediate liner type, with higher engine efficiency, combining high speeds and smaller dimensions, together with absence or lessening of vibration.

J. S. ORMISTON (Genoa).

The Association is to be heartily congratulated on the excellent symposium in six sections on the important and fascinating subject of large passenger liners.

Notwithstanding the enormous cost of such structures they are still being built and no one can assert that a definite arrest in their dimensions and consequent cost appears yet in sight.

To the interesting list of features indicating changes in general design enumerated under sub-title "Progress in General Design and Appearance," one may add the omission of the mainmast in the case of a recently built high-class passenger vessel.

As the author states, there is no doubt that the social and sports life of the traveller is well catered for aboard modern large passenger vessels, but it is quite an open question, in my opinion, whether this is not being very much overdone.

It seems desirable and almost necessary for a large passenger vessel to have one spacious dining hall for *de luxe* and first-class passengers so the "inner man" requirements of these may be dealt with at one sitting, but it does seem debatable whether such large lounge halls and salons are not really excessive.

During how many hours of the day on a transatlantic voyage are these large social apartments used to any extent? I gather for a very small part indeed and so one may naturally ask whether they could not be reduced in size and the space used for additional cabin accommodation.

Referring to the proportions of large passenger ships it seems to me fortunate that proportions of L/D have been reduced, otherwise thicknesses of material on strength decks would become quite excessive and out of proportion to the shell plating and to the frames and beams which support and stiffen the strength deck plating and through which the latter is enabled to exercise its proper function.

The development indicated in the third paragraph from top of page 4 seems a good one and such a feature should tend to assist in reducing the number of tiers of deckhouse superstructures.

In addition to the cofferdam above deep oil fuel bunkers now commonly adopted and referred to near top of page 5, in one or two cases also has been fitted a steel cofferdam from ship's side to ship's side at the fore end of the range of deep oil bunkers, separating these from the adjacent cargo holds.

Referring to the author's remarks regarding corrosion increases in double bottoms in way of boilers, it would appear doubtful whether even the increase indicated by author is necessary if water tube boilers are fitted.

I do not quite agree with the author when he says in the same paragraph that normal stiffening of bottom forward against pounding is often not so necessary. Large passenger vessels with bulbous bows have a definite flat of bottom forward and although the bottom forward of large passenger vessels does not often rise out the water, it is sufficient for this to happen only once or twice for extensive damage to be sustained and to a degree also in such vessels of normal form.

Undoubtedly, divided uptakes or any arrangement of deck openings resulting in a separation of deck material from the ship's sides reduces very greatly the contribution to strength of such isolated parts of the deck, unless some very effective vertical structure for developing the resistance of such parts can be arranged; as the author indicates this is to a great extent precluded by the lay-out of accommodation.

A feature which has been adopted in some large passenger vessels namely, longitudinal non-watertight but robust steel bulkheads—one each side of centre line of vessel—from aft end of machinery space to extreme aft end of counter at aft end of vessel and vertically from the inner bottom to at least the strength deck, with suitable openings in same for cross communication adequately compensated, indicates, however, the possibility although these longitudinal bulkheads were, I think, fitted principally for the purpose of reducing vibration and this with successful results.

Referring to this elusive subject of vibration, my opinion and experience are, that as regards the after part of the vessel, the above-mentioned longitudinal bulkheads are most efficient preventers of vibration. Above the deck to which they extend it is not impossible to arrange for their function to be continued through efficient deck girders and pillaring and in some cases also through deckhouse sides.

Further, regarding the author's reference on page 6 to increases in scantlings of deck beams, girders and pillaring as a basis for minimising vibration in large passenger vessels, there is no doubt such increases are very effective and in this connection I am of the opinion this should be carried out in association with reinforced deck beams at intervals in addition to pillar requirements.

Further, a definite maximum ratio of depth of deck beam to its span could, without undue increase in weight, be adopted and this should not, in my opinion, exceed about 12 and certainly not 15 at the very outside, in certain parts of the decks at the after part of the vessel. If such a ratio is maintained in association with the special reinforced transverse beams—just referred to—of say same depth as the longitudinal deck girders, considerable reduction in vibration should result.

These remarks, I suggest, apply to large passenger vessels with service speeds of from 25 to 30 knots.

Coming now to the sub-title "Longitudinal Strength" I would ask the author if he would be so kind as to explain exactly the reason for what he there sets forth, namely, that as in large passenger ships, in which the draught is small compared with the dimensions of the vessel, the bending moment does not vary in direct proportion to the draught.

It has already been brought to the notice of the Members of this Association—*vide* Mr. W. Thomson's 1921-1922 Paper on Oil Tankers—and my 1923-24 Paper for Ordinary Cargo Vessels—that the normal tensile and compressive unit stresses at top and bottom of the ship's girder section corresponding to load draught and a standard uniformly distributed cargo of homogeneous nature are not necessarily the most serious (as my Paper for cargo ships particularly shows), for at draughts less than the load draught relatively high and serious stresses result as a result of concentration of loading.

Now in a large passenger ship it is difficult, nay almost impossible, to realise concentration of loading such as has been experienced in cargo ships, for I take it a request for increase in draught of a large passenger vessel would be probably for one, or possibly two, of the following reasons :—

(1) Increase in weight of oil fuel carried.
(2) „ „ „ „ machinery.
(3) „ „ „ „ cargo.

and possibly, but less likely, weight of hull structure, so I would be obliged if the author would clarify the matter in his reply to the discussion.

The question of main longitudinal strength is of course always important, but experience, I think, shows that close attention to detail in all parts of the hull structure of a large passenger vessel is very necessary as damage due to heavy weather in almost all cases is in the nature of straining of relatively local parts of the structure, due in some cases at least to features such as bulbous bows as indicated by the author himself in the third paragraph from top of page 7. In this connection also there is no doubt whatever that height above still water level has little relation to the damage which may result from heavy weather.

It is not out of place also, in my opinion, to note that the construction and attachment to effective hull structure of some so-called non-structural parts, as for example longitudinal and tranverse divisional bulkheads, leaves something to be desired if owners are to be avoided annoying and often costly repairs during the service of the ship.

In conclusion, I would congratulate the author on this well-written and very readable section dealing with the structural aspect of development as part of this admirable symposium.

J. Hodgson (Barrow).

This subject, being so extensive, can only be dealt with in a general way, in the space of a short paper, and the author is to be congratulated upon having given us a very comprehensive survey of all recent developments.

The amenities of a first class luxury hotel, now provided on most modern passenger ships, have undoubtedly popularised ocean travel and cruising, and thereby increased the earning capacity of such ships.

Under the heading of general design and appearance the owners must of necessity pay some attention to contemporary taste, but it is essential that the finished structure should have an appearance which will be at least pleasing to the majority ; the avoidance of extremes is more likely to attain the desired result. The fashion of two or three "funnels" has again reverted to one funnel and even one mast in some of the latest ships. One funnel in a moderate sized vessel has the advantage of allowing a greater expanse of sports deck.

With regard to proportions, it is true that slightly greater initial stability is now being provided, but an increase of beam ratio is necessary on account of lighter machinery combined with larger superstructures and elevation of heavy topside material.

For longitudinal strength the great depth of the girder available over the midship portion together with the number of decks is ideally suited to the economical provision of ample strength, once the criterion of strength has been decided upon. Having regard to the number of variable factors involved, it would seem prudent that the longitudinal strength of such large vessels should be separately investigated rather than based upon empirical coefficients, especially in the case of high speed Atlantic ships.

The extent and tapering down of the main strength superstructures, emphasised in the paper, is of great importance. The present tendency to increase the size of embarkation doors and to fit rectangular windows instead of circular lights in the topsides, also requires careful consideration, as in some cases adequate compensation is difficult.

The problem of light superstructures above the strength deck has become more difficult on account of the demand for many large windows and doorways with very low sills.

It is doubtful if only one expansion joint in a long superstructure really affords much relief. These joints are often situated in positions where minimum pillaring is desired and are then frequently a source of noise.

The use of special quality steels for topsides and superstructures with its attendant reduction of weight has helped the stability problem. The question of fitting such steels, however, is sometimes merely one of economics in building, i.e., reduction in weight *contra* extra cost of steel.

The arrangement of oil fuel bunkers referred to at the bottom of page four, in which the tank top plating is stopped at the longitudinal oiltight bulkheads, has been fitted in several recent vessels. In some cases the side bunkers are common with the double bottom inboard to the second side girder which is made oiltight. This arrangement has raised an interesting question under the sub-division regulations on the point of heeling after bilging on one side, for which levelling pipes have been provided across the ship. It is understood, however, that the arrangement is being discouraged by the authorities, and it is probable that an inner bottom covering the bilge to the height prescribed in the regulations may again be the usual practice.

The provision of a horizontal cofferdam over the top of the oil bunkers has many advantages as stated in the paper ; it also provides a convenient space for the running of large diameter pipes usually fairly numerous in this region. This cofferdam is frequently situated at, or just below, the waterline, and in some ships it is entirely open to the machinery spaces for ventilation reasons. Such an arrangement greatly reduces the side protection afforded by the side bunkers as well as the structural contribution of the longitudinal bulkheads.

A problem which has arisen, as a result of the adoption of large W. T. boilers, is the available deck height in the boiler rooms of the moderate sized ship. Very low seatings have been fitted, and in some cases the inner bottom has been slightly lowered. In some of these ships very high temperatures have been experienced at the tank top necessitating the fitting of heat-proof cement. Any reduction in the corrosion increases in thickness in such cases would seem to be undesirable, also the carrying of oil fuel in the double bottom under such boiler rooms seems to require some reconsideration. One solution would be the curtailment of the lower deck over the boiler room, but this means loss of valuable deck space.

The problem of vibration referred to on page 6 is of very great importance in all passenger ships, and turbo-electric propelling machinery has been a valued contribution to its satisfactory solution, as all who have travelled in such vessels testify to their smoothness.

At the same time modern engineering practice has succeeded in reducing considerably the vibration of geared turbine machinery, so that the question does not now appear to be such an influential factor in the choice of type of machinery, and some companies which adopted turbo-electric drive have reverted to geared turbines.

Whilst the elimination of the cause of vibration is chiefly the engineers' problem, much can be done by the shipbuilder to minimise its effects, and the point, made in the paper, that the ship's architects should arrange their schemes of decoration and accommodation within the requirements necessary for an efficient structure is of supreme importance in the present stage of development of these ships. The most important and desirable of these requirements though seldom possible in practice, is that all pillars should be vertically in line; care and detail attention in designing, and a spirit of compromise will generally produce an efficient arrangement.

Concentrated loads stepping on flexible girders constitute always a possible source of local vibration, and where they cannot be avoided extra stiffness in the girders should be provided. Detailed attention to the structure above and below pillars in order to obtain hard bearing fits is also helpful, and to this end electric welding has been of great benefit. The necessity for stiffness in deck girders is now generally realised, but in some cases restricted head room over beds has necessitated the fitting of inefficient types of girders and long span girders in public rooms and open spaces are not always as deep as they might be.

In some cases something more might be done at the stern in way of the bossing to absorb the impulses of the propellers. In some ships a longitudinal centre line bulkhead has been fitted throughout the after tunnel space with beneficial results. If this bulkhead is watertight, it serves the additional good purpose of isolating the effects of serious damage to one tail shaft. Web frames are useful members against vibration but the web frames now fitted in the topsides in conjunction with lighter side frames are not always sufficiently rigid.

With regard to the remarks under the heading of "Stems and Sterns," it still appears doubtful whether any of the extreme ideas as regards form possess the overall efficiency claimed for them. It is interesting to mention that in some recent 25,000 ton ships the tank experiments showed that a well designed normal form was distinctly better than a "Maier" form at the required speed.

The intensive search for economy in cost of building has eliminated castings altogether from the stems of some recent large ships. The whole stem from keel to deck is of fashioned plates, those at the fore foot being of boiler quality steel in short lengths pressed hot; the butts are electrically welded as are the internal supporting webs. The radius of the stem is gradually increased from above the water-line to the deck, as mentioned in the paper. The wider deck space at the top, in addition to providing extra space round the anchor gear, affords ideal stowage in the top 'tween deck for a canal searchlight for which a shutter is provided in the stem head.

A reduction in the weight of spectacle frames has also been affected by arranging a thinner barrel with circumferential and longitudinal ribs.

Mention has been made of the large increase in the piping systems and ventilating trunks now required for water services, and air conditioning arrangements now provided for passengers. The maintainance of the strength of deck girders in way of passing trunks and pipes requires increased attention, and incidentally this provides additional argument for adequate depth in the girders.

The details of construction of these vessels and especially the pillaring arrangements have been greatly simplified and made more efficient by the use of electric welding.

R. Crawford (Bilbao).

The authors have given us an excellent resumé of the recent developments in large passenger ships, which is singularly opportune, in view of the intense interest displayed at the present time by all connected with marine affairs. Every member of the Association owes to them his thanks and appreciation. The information and tables of data will prove most useful to all Members, and must have taken a great deal of time to compile.

There are one or two further notes which the writer wishes to add which may prove useful.

Pages 3 and 4, Superstructures.—In order to overcome the horizontal shearing stresses in the topside riveting at the breaks of the strength superstructures, the side plating of the superstructures is very often carried down to the deck level, thereby obtaining a good connection to the continuous gunwale angle and sheerstrake below.

In large vessels a great deal of the noise or creaking, which is sometimes experienced in the superstructures, is in the writer's opinion, caused by racking or working of the massive top hamper in the transverse direction, and a much stiffer structure and less noisy one might be provided by arranging the transverse bulkheads and partial transverse bulkheads directly in line or as near as possible in line with the main sub-division bulkheads. This arrangement also minimises vibration, and it would be as well to very carefully consider it in the early stages of the design.

Page 4, Main Structure.—In the case of the "MANHATTAN" where the longitudinal oil-tight bulkheads are carried down to the bottom shell, it would be interesting to know whether any reduction was made in the thickness of the bottom plating (compared with other similar vessels, but without this arrangement) on account of the additional longitudinal strength provided by these longitudinal bulkheads.

Some reduction has sometimes been made where the girders in the double bottom have been made continuous, and in at least one case a further advantage was gained by a smaller diameter of rivet being allowed on account of the reduced thickness of bottom plating.

Page 7, Details.—Another recent development which might be added to this section is the use of electric welded chain cables of special steel (having a tensile breaking strength of 31 to 35 tons per sq. in.) which will withstand breaking loads 40 per cent above those of ordinary fire welded cables.

Pages 6 and 7, Stems and Sterns.—With regard to cast steel stems and sternposts and also shaft brackets and rudder frames, the modern tendency is to increase the scantlings of the body of the casting, and reduce the number of webs and fillets, which greatly simplifies the casting, and avoids shrinkage cracks.

REPLY BY THE AUTHOR.

It is interesting to note that Mr. Blocksidge thinks the maximum limit in regard to the size of large passenger ships has now been reached and that he and Mr. Bennett both consider that development in the future will be in the direction of smaller vessels driven at increased speeds. In contrast to these opinions, Mr. Ormiston says that no one can assert that a definite arrest in dimensions and consequent cost appears yet in sight.

In any project of the "mammoth" type the design has to be based upon circumstances and demands which are expected to prevail when the vessel is trading, but between the time of design and the time of entering service there will be an interval of some three to four years during which there might be a radical alteration in many of the conditions on which the design has been founded. This constitutes a serious risk for the shipowner. From the technical point of view the limit in size has not been reached, but the present tendency for countries to become more self-dependent and self-contained is likely to restrict intercommunication and reduce the demand for overseas transport.

It is not thought that the proportion of L/D has been reduced in order to prevent the strength deck material from becoming excessive, as inferred by Mr. Ormiston. It is suggested that the real reason lies in the modern demand for enclosed superstructures to accommodate public rooms and sports spaces instead of providing long open promenades at the ship's sides. The naval architect has therefore taken advantage of this development by raising the strength deck thereby obtaining a concession in weight without loss of strength and securing a gain in stiffness.

Completely diverse opinions are expressed by Mr. Ormiston and Mr. Hodgson in respect of the corrosion increase in double bottoms in way of water tube boilers. Mr. Ormiston is doubtful whether any increase is necessary whilst Mr. Hodgson says that any reduction in the corrosion increases would seem undesirable. The practice quoted in the paper refers to deep well-ventilated double bottoms with a reasonable distance between the tank top and the bottom of the boilers. Where these conditions are departed from, special consideration of the scantlings would be necessary but it would be rather surprising to find a large passenger ship where the height in the boiler rooms is restricted.

The remarks in the paper regarding strengthening of bottom forward apply, as stated, to *very large* vessels and in such cases it is often unnecessary to provide the same standard of stiffening as in the ordinary cargo vessel. The exact nature and extent of the strengthening will depend on the size of the vessel and its form forward, and also upon the existence of any special features such as the bulbous bow.

Mr. Ormiston and Mr. Hodgson refer to the fitting of longitudinal steel bulkheads in the after part of the vessel. This arrangement is undoubtedly an excellent one for reducing vibration especially if the bulkheads are arranged in line with the pillaring of the passenger decks above.

Messrs. Thomson, Ormiston and Hodgson refer to the remarks in the paper on "Longitudinal Strength." The condition of loading usually considered when comparing the strength of large passenger vessels is the "arrival" condition, and the bending moment derived therefrom is relatively greater than for a cargo ship under similar conditions. Calculations for early large vessels showed that the bending moment coefficients were less than had been expected and during recent years, when depth has been increased without a corresponding increase in draught, the bending moments coefficients have become still less. The author and Mr. Balfour, from independent investigations, came to the conclusion that the depth of the structure in relation to the draught had an unexpected influence on the bending moment and that the bending moments in vessels having similar characteristics but different depths of structure will not be proportional. This applies primarily to different ships of the same type under similar conditions and not to one ship under varying conditions of loading and draught as assumed by Mr. Ormiston. It is well known that at draughts less than the load draught relatively high and serious stresses can result in cargo ships due to concentration of loading as stated by Mr. Ormiston, but these conditions are not normal ones and the scantlings are not usually based on them. In the case of the large passenger ship the "arrival" condition is not an abnormal one.

As regards Mr. Thomson's remarks it might be pointed out that Mr. Balfour's investigations were made on a theoretical basis but the author's analyses were based upon actual results and data. When the same conclusion is reached from these two methods it is scarcely correct to assert that there is a lack of definite knowledge. Although the suggestions put forward appear untenable to Mr. Thomson he advances no other reason to explain the difference which exists between vessels of the type under consideration and other ships. It is true that their number is relatively small but in no case will an extension of the International Standard of Longitudinal Strength satisfy the requirements of the large passenger ship.

It is agreed that the variation of the calculated stress in accordance with $\sqrt[3]{L}$ is a refinement. In practice the corrections due to change in block coefficient tend to eliminate those due to change in speed.

Mr. Hodgson says that it would seem prudent that the longitudinal strength of large vessels should be separately investigated rather than based on empirical coefficients. This is unquestionably the best way and the one which, scarcely without exception, is adopted in practice. But one must not lose sight of the fact that before a design can be formulated many estimates have to be prepared and their correctness verified later by a system of trial and error. The Classification Society is usually approached in regard to the desired scantlings before any detail strength calculations have been made by the builders. Careful analyses have shown that a very close approach can be made to the scantlings provided there are no unusual features which will influence the strength and it inspires confidence and is more dignified to indicate the requirements than to wait until the builders have completed their calculations.

The longitudinal strength of these large vessels is a very great subject and cannot possibly be dealt with within the scope of the paper.

In reply to Mr. Crawford's enquiry regarding the thickness of bottom shell plating it might be pointed out that in large vessels, which lie outside the Society's Tables, it is usual to base the scantlings of the bottom shell plating on the length, draught and frame spacing and, as in most vessels of this type it is necessary to have longitudinal girders in the double bottom, it is not seen why any reduction in thickness should have been made in the bottom plating in the "MANHATTAN" due to the longitudinal oil-tight bulkheads being carried down to the shell.

PART I.—(b) PROPELLING MACHINERY.

By R. LEE ANNEAR.

W. Cowie (Southampton).

The very comprehensive summary given by the author of the developments in marine propelling machinery installations, which have marked the post war years, is a valuable contribution to the transactions.

The search for economies in performance, and the competition between the internal combustion engine and steam engine, together with the advance in metallurgical science and practice, has accelerated progress so rapidly that machinery designed in 1920 is practically obsolete, and, had it not been for the depression in the shipping industry, we would probably have seen a large number of vessels re-engined.

A very interesting feature as shown by the paper is that Diesel engines, geared turbines and turbo-electric types have been fitted in recent years in vessels of similar capacity and class for trades not very different, and one is rather curious to know what had been the determining factor in the choice. The single reduction geared turbine, with electrically driven auxiliaries, is, however, still probably the most popular type for high-class passenger vessels. The adoption of water tube boilers, with pressures of 400/450 lbs. per sq. in., and superheat to 750° F., is now general, and the remarkable efficiency of the boilers has been a factor in the very low fuel consumptions for these installations of around ·6 lb. per S.H.P.

The turbo-electric drive has much to commend it for this class of vessel. Its flexibility and absence of noise, maximum astern power without having to introduce special units for this purpose, are advantages of great import. The chief objection to its more general adoption appears to be the transmission losses.

The large number of units comprising Diesel engine machinery for the power required in this class of vessel, and the heavy reciprocating masses, with the danger of noise and vibration, seemed to have outweighed the low fuel consumption possible with this type. Where, however, the owners have had courage to adopt it, their confidence appears to have been justified.

Advances in design of all types of machinery involving higher pressures and temperatures has been encouraged by the improvement in materials and workmanship. In turbine design, the increased rotor speeds have become possible by the improvement in manufacture, in testing and securing of the blading and accurate balancing. Gearing has greatly improved in precision of machining, the balancing of wheels, and the introduction of the enveloping and all addendum tooth.

Improvements in foundry practice have been considerable, and the ability to manufacture reliable steel castings of large dimensions and intricate design has made high pressures and temperatures possible. The hot mould process, together with the wider use of high-grade irons and semi-steels, has given engineers reliable castings, having shock and heat resisting qualities far superior to the ordinary irons, and has lent confidence in the development of the large units of the present day Diesel engine.

In this district, between 1924 and 1935, five vessels have been completed for one company; all of similar dimensions, the machinery in each case being single reduction geared turbines with electrically driven auxiliaries. The first vessel was fitted with cylindrical multitubular boilers and smoke tube superheaters, the pressure being 215 lbs. per sq. in., and steam temperature about 600° F. The vessel completed last year has water tube boilers and interdeck type superheaters. The pressure is 450 lbs. per sq. in. and steam temperature 750° F. It is stated that the economy shown in the latter vessel is about 25 per cent. over that of the 1924 ship, which may be taken as the measure of progress in eleven years.

REPLY BY THE AUTHOR.

My contribution to the omnibus paper was in no way original or exhaustive. It quoted installations which, in my opinion, indicated the trend of modern design of machinery for passenger ships.

As Mr. Cowie states, "one is curious to know what has been the determining factor in the choice" where so many types of engines have been fitted in recent years in vessels of similar capacity and class for trades not very different.

It is essentially a question of commercial economics, but not easily explained. For light-weight high-powered propulsion units the high economic efficiency obtainable from the use of higher pressures and temperatures has to be combined with the comparatively slowly-rotating highly-efficient propeller.

Mr. Cowie cites the advantages of turbo-electric drive for this form of geared propulsion. If, and when, the electrical engineer can reduce the cost and losses of this form of transmission, it will be more generally adopted.

The Föttinger hydraulic drive was an attempt which may yet be further developed to accomplish this objective, although its adoption hitherto has been more as a flexible coupling.

About twenty-five years ago it was hoped that double reduction mechanical gearing would solve the problem, but this form of gearing is now rarely used. There still seems a wide field for design of high pressure steam units, as for marine purposes pressures up to 800 lbs. per sq. in., and for land engines pressures of over 1,000 lbs. per sq. in., have been tried. For heavy-oil propulsive units, the adoption of solid injection of the fuel removed the troubles occasioned by the high pressure air compressor, and, by means of the waste gas boiler, recovery of much heat from exhaust gases is possible. The limit of size of cylinder would appear to be one metre diameter, and the later experiments have been directed to accomplish weight reduction by the more general use of steel instead of cast iron.

What is a most remarkable feature of modern passenger vessels is the huge increase in the "hotel" load. This is almost entirely an electric service. As the auxiliary units are, in almost all cases, independent of the propelling units, the auxiliary engine room of tne modern liner is the centre of the most intimate activities, including the power for lighting, heating, refrigerating, steering, cooking, pumping, ventilating and other plants.

Since the paper was written there have been two record-breaking examples of modern passenger vessels, the "QUEEN MARY" and the "STIRLING CASTLE," the first of a steam geared turbine and the second of a double-acting oil engine, which, in their respective spheres, have enhanced the credit of the modern shipbuilder.

PART I.—(c) FIRE PROTECTION.

By C. W. REED.

W. Thomson.

Mr. Reed's description of the methods adopted for the detection and extinction of fires on board ship is so complete that little can be added. The advocates of the various devices are each very insistent on the superior merits of his particular nostrum and perfectly certain that the employment of his particular system would lead to the abolition of losses of ships by fire.

The most recent official regulations are those issued by the French government which go considerably beyond the requirements of the International Convention. Not only are the standard fireproof bulkheads to be fitted at intervals of 131 feet but each compartment thus formed is to be sub-divided into areas of about 530 square yards and these again further sub-divided into areas of 170 square yards. Elaborate details are given of the fire-resisting properties of each type of bulkhead to be provided for these sub-divisions, but it is even required that carpets and curtains after cleaning are to be again fire proofed. Careful as these regulations are to provide against all contingencies, there is little doubt that the best safeguard of all is the provision of an adequate fire patrol and that there is no adequate substitute for continual vigilance on the part of the crew.

G. O. Watson,

In connection with this subject, Mr. Reed quite rightly summarises the "causes" as a necessary preliminary to dealing with prevention and since the electrical installation, rightly or wrongly, is so frequently blamed for fires a further analysis of these cases might profitably be made. We electrical engineers are becoming hardened to the false accusations so frequently levelled at electrical installations as the cause of fires. While not denying that there are potential dangers if upkeep and maintenance are neglected or installation is not in accordance with the requirements of the rules we do know that every time a fire occurs which cannot be otherwise accounted for, it is assigned to "short circuit." Many cases could be quoted where fires in buildings have been so assigned where the building has not been even wired for electricity.

In one instance a fire was started by blankets being placed in a store room by a steward who left an electric radiator switched on. The blankets slipped down into contact with the radiator with obvious results. In another very similar case, an engineer joining a new ship thought his blankets needed airing so he spread them in front of his electric radiator with the same consequence. As a result the superintendent had every radiator removed from the ship. The Society's Rules now forbid luminous radiators in cabins, etc., and require them to be of the non-luminous or convector type operating at black heat.

Another type of fire was started in an engine room as a result of a jet of oil from a burst pipe impingeing on a lamp fitting from which the protecting globe was missing.

Chafing of cables where they pass through beams or bulkheads is a frequent source of danger and these points should be specially examined during construction and at times of Periodical Survey.

Passing on to the question of prevention, it is evident that the author is very sceptical and non-committal on the subject of rendering timber fire-resisting for he uses expressions such as "it is claimed" and "so-called" and one is left with a grave doubt as to the efficacy of these methods.

Some serious fires have taken place while ships have been under construction, and to those acquainted with the conditions they are not surprising. Accumulations of wood-shavings and other inflammable materials are to be seen in proximity to rivet fires and oxy-acetylene cutting operations, etc. One also

observes the risky nature of the temporary lighting cables. In this connection it would tend to reduce risks if the ship's wiring were completed as early as possible and use made of it to supply temporary lighting as far as practicable.

Then again there is the very necessary precaution of stopping the supply of ventilating air to the seat of the fire. Some owners now make provision for all ventilating fans to be controlled for stopping purposes from the bridge. In the case of the "P. C. HOOFT" which was burnt out on the Continent, a year or so ago, it was disclosed that subsequent to fumigating the ship the fans had been left running to clear the fumes. On the outbreak occurring it became impossible to stop the fans and the damage was much greater than would otherwise have been the case.

The author describes some of the methods of fire detection in use. Other systems for electrical detection depend on the unbroken continuity of electrical circuits, so arranged that a break will cause an alarm to be given. One of these consists of a strip of low melting point metal foil between two layers of paper, approximately half inch wide. The strip can be glued around the walls of cabins and painted over. The suppliers counter any criticism that the fire must reach the walls before the alarm is given by asserting that the fire is not "serious" until it does so.

Another system, similar to that described by the author, wherein sprinkler bulbs are used to operate an electrical alarm device, consists of a small glass bulb containing a highly volatile liquid. It is so constructed that at a pre-determined temperature the liquid has expanded to the full extent of the tube which then bursts. The outer surface of the bulb is metalised and completes the electric circuit, so that the bursting of the bulb breaks the circuit.

S. TOWNSHEND (Gothenburg).

Under the heading "Cause" the author, in his excellent paper, says that it is difficult to assign the cause of most shipboard fires, as the evidence is usually destroyed by the fire itself. Then follow certain fire statistics which unfortunately do not descriminate between the large passenger vessel and other types. It does, however, appear from the figures given that about 75 per cent. of the fires, the causes of which are known, occurred in the cargo and fuel, 22 per cent. occurred in the machinery space and 2 per cent. elsewhere. These percentages suggest that investigations in regard to outbreaks of fire should have been directed to cargo and fuel spaces. Yet, in spite of this, very great attention has been focussed in recent years on the passenger accommodation and the ship's structure.

The reason for this might possibly be found by quoting the statistics for large passenger vessels. Out of the total of 688 fire outbreaks referred to by the author, 21 cases occurred in ships between 10,000 and 15,000 tons gross and 10 cases in vessels of over 15,000 tons gross. These figures, in themselves seem small, but when they are expressed as a percentage of the total number of ships in each category the comparison becomes very different. This is shown in the following table which includes only steam and motor ships :—

Size of Ship (gross tons).	Total Number of Ships.	Number of Fire Outbreaks.	Ratio of Fires to Number of Ships.
Above 100	29,996	688	2·3 per cent.
Between 10,000 and 15,000... ...	292	21	7·2 per cent.
Above 15,000	156	10	6·4 per cent.

The table indicates that fire outbreaks are much less frequent in small vessels than in large ones, the large passenger ship obviously being very vulnerable in this respect.

Further, the investigations indicated, in regard to vessels holding British Passenger Certificates, that 11 outbreaks occurred in the cargo holds, 3 in the machinery space and 9 in the passenger or crew accommodation. These figures show that the risk in the cargo and machinery spaces in the passenger ship is

about the same as in the cargo ship, but that there is added risk in the passenger ship of fire in the accommodation and the figures also indicate that the latter risk is almost as great as the risk of fire in the cargo.

The foregoing, taken in conjunction with the disastrous fires on large vessels which have occurred in recent times, point very clearly to the importance of dealing with the subject of fires on board large passenger ships.

One is apt to get the impression that little progress has been made in recent years in the matter of fire *prevention*, for, in spite of the title, the author has devoted only a small section of his paper to this subject. It might indeed almost seem that little has been or can be done to prevent fire on board ships, that the risk of fire-outbreaks has to be accepted as ever-present, and to a certain extent, unavoidable and that attention must be directed more to the detection, restriction and extinction of an outbreak than to its prevention. I do not, however, believe this impression represents actual fact for much has been done in recent times to reduce the risk of fire-outbreak and attention is drawn to the amendments made in recent years by the Committee of Lloyd's Register which have this objective in view. Prevention is better than cure and I suggest that these and other matters might have been referred to in order to indicate that progress has been made in preventative measures besides the fire-proofing of timber, the production of fire-resisting paints and the improved regulations regarding electrical equipment.

Under the heading "Prevention" the author says that for passenger vessels it is considered that by far the best is the human patrol. Undoubtedly this arrangement is the best detective and restrictive measure, as stated in the paper later on, but I question whether it has much value as a preventative. In order to be effective as such it would be necessary for several patrols to be on duty at once in a large passenger ship and they would require to have authority to demand access to the passenger cabins at all times of the day and night. Such a strong disciplinary measure would never be tolerated.

An arrangement for restricting the vertical spread of a fire outbreak through the ventilators has been adopted in some vessels recently built for Italian owners. A steel baffle plate, capable of being rotated through an angle of 90° is fitted in the ventilator. The baffle on its normal open position lies in a vertical plane and is closed by being turned into a horizontal position. Such an arrangement is also of value when it is desired to smother a fire-outbreak by shutting off all air inlets. The idea is useful in the case of concentric ventilating shafts for preventing the spread of fire from one compartment to another whilst it can also be applied to the horizontal ventilating trunks in passenger vessels. Perhaps the author can say if such arrangements have been employed in these vessels.

Mr. Lee Annear in his paper gives some particulars of fire fighting arrangements in the machinery spaces and those interested in the subject will find the reference in the middle paragraph on page 12.

REPLY BY THE AUTHOR.

It was not expected that any discussion on a paper of this type would be forthcoming, which redounds to the credit of those who have taken the trouble to contribute.

Mr. Thomson, as usual, is to the fore, and his words of praise are appreciated.

It is interesting to note the extreme measures adopted by the French Government against the possibility of fire, such measures, no doubt, being prompted by the panic following the "Georges Phillipar," "Asia," "L'Atlantique" disasters.

Whether such routine details as re-proofing of curtains and carpets after cleaning will be rigourously carried out, and whether they are necessary, is a moot point.

It is noted that Mr. Thomson agrees with the author in the efficacy of the human patrol, without which the most elaborate precautions are often valueless.

Mr. G. O. Watson has submitted a most interesting discussion. We have all been amused and rather angry at the usual cries of the Press that each and every disaster at sea is caused through "short circuit."

It may be that electric wiring and fittings on a ship are a source of danger if abused, like every other useful invention; but there is no reason why, with care, good workmanship, and common sense in use, any fires should be caused through them.

It is difficult to guard against such cases as quoted, such as leaving on a radiator in a blanket store.

Now that electric installations come under the supervision of the Society's Surveyors in Classed ships, much faulty wiring and overfusing will be detected and so many fewer fires occurring. It is very difficult, however, for the keenest Surveyor to bring up to scratch all at once the wiring in old ships, but faults will be gradually eliminated, with time and care.

Now that fewer ships are laid up for long periods, fewer mysterious "earths," due to damp, will be found.

The author confirms that he has not been impressed, during the many experiments he witnessed, with the efficacy of patent timber fire-resisting processes, nor of most of the "fire-proof" paints.

It is very important that means be provided for shutting off from decks means of ventilation to the to the seat of the fire, such as fans, ventilators, etc.

The fire detection methods, described by Mr. Watson, using electrical circuits are noted with interest, but it would seem that a drawback against these methods would be that when the ship was in port at any time with the electricity "dead," then these systems would be useless.

It was, of course, impossible in the paper to attempt to describe all systems of fire detection, prevention and extinction, but only a few typical systems or ideas were described—more especially as in the last few years fresh systems, patent materials, paints, etc., have been put on the market almost every week.

The author is obliged to Mr. S. Townshend for amplifying his statistics of fire causes by quoting from the author's memorandum on "Fires in Merchant Ships," prepared some time ago, but now presented in a more interesting way. Mr. Townshend thus brings out that large passenger ships are more vulnerable than small vessels, which agrees with the popular conception.

It is regretted that Mr. Townshend thinks that light has been made in the paper of the recent efforts in fire prevention, as distinct from detection and extinction, but the author assures him that this was not the intention of the paper, but that limitations in the size of the paper caused him, necessarily, to curtail much that might have been said. Mr. Townshend appears to draw a fine line between "prevention" and "restriction" of fires in connection with the value of patrols, but, it is surely the case, that if a patrol or apparatus "restricts" a fire from spreading, he prevents a larger fire, and thus the word "prevention" may justly be used to cover both "prevention" and "restriction."

In general, it might be added that such far-reaching developments in methods of dealing with fires on shipboard, and especially on large passenger ships, have taken place since the dim ages when the paper was written, that it is a pity it could not be re-written on a much larger scale.

However, if the paper has given to such colleagues in outports, who may not have had much to do with methods at present in use on shipboard to combat fires, some idea of the general principles involved, the author will feel happy at having performed some slight service.

PART II.—(a) LIFE-SAVING APPLIANCES.

By E. W. BLOCKSIDGE.

J. S. Ormiston (Genoa).

The provision of an adequate outfit of life-saving appliances on board ship has for some time been and should always and constantly be the subject of careful attention of legislators and owners.

As the present paper clearly shows, great advances have been made, and while one should not be too dogmatic in such an important matter, it does seem as if present life-saving appliance arrangements in general aboard large passenger vessels were as perfect as they can possibily be from the design point of view.

One is, I think, justified in coming to such a conclusion by considering the life-saving appliances aboard a modern passenger ship, and bearing in mind what the author describes on page 2 of paper as the first and most important line of defence against casualty.

It would be interesting if the author could indicate to us the average per cent loss to which the small casualty figures quoted by him near bottom of same page correspond. It must be a very small ratio indeed.

The advent of the gravity type of boat davit, as the author states, has greatly increased the efficiency of boat lowering apparatus, and I should imagine we have in this type really the "last word" for such apparatus, excepting perhaps for minor modifications and improvements of the type and its accessories.

It follows then, I think, that the survey, maintenance in good working condition together with constant attention and faithful carrying out of regulations relating to musters and drills would seem now to be the important thing in connection with life-saving appliances, and this is no trite saying, for unless those are rigidly and periodically attended to, the design and construction efficiences of modern outfits aboard ship for the saving of life at sea in case of casualty, are defeated, and that which is intended as a provision against an emergency in which the lives of two or three thousand people may momentarily be at stake, becomes useless as such.

I would congratulate the author on his important contribution to this general subject of recent general developments of large passenger ships.

REPLY BY THE AUTHOR.

The subjects included in this paper are of a special character and do not invite discussion. Letters of appreciation have, however, been received from Surveyors in the remote corners of the Society's sphere of operations and who welcome the efforts of members to distribute information in such a form for easy reference.

My old colleague, Mr. Ormiston, draws attention to several important features of the subject, particularly in regard to the necessity of faithfully carrying out the regulations relating to musters and drill.

With reference to his enquiry as to the ratio of the loss of life referred to in the last paragraph on page 2 of the paper, it is difficult to obtain reliable information relating to the total number of passengers carried on all classes of ships, but the author has in his possession the numbers of passengers carried on the North Atlantic Service for the past three years and the percentage of loss is less than one, which can be considered as negligible.

The number of ships lost at sea of 1,600 tons gross tonnage and upwards and registered in the United Kingdom averaged 1 in 156 in 1920–22 and 1 in 242 in 1932–34. The number of officers and seamen lost in 1910–14 averaged 1 in 412, and in 1932–34 in was 1 in 2,360. The number of passengers lost in the years 1910–14 averaged 429, and in 1929–33 the average was as low as 22, the percentage of loss being negligible.

These statistics show a steady improvement every year.

As past-president of the Association I desire to thank my five colleagues who combined to bring into one paper the results of their investigations into the various subjects of importance associated with the modern passenger ship.

PART II.—(b) SUB-DIVISION.

By S. T. BRYDEN.

G. Buchanan (London).

In this paper we have a very comprehensive comparison between the requirements of 1915 and 1932, and the part of the paper which interests me most is the portion dealing with the spacing of bulkheads, as I had occasion, some time ago, to carry out a somewhat similar series of calculations comparing the two sets of rules.

Instead of varying the draught and keeping the same spacing of bulkheads, I kept the draught the same under both sets of Rules and found the number of bulkheads required.

Two types of vessel were considered, practically the same as the author has done. In the vessel of the passenger type, in which the carriage of cargo is of relatively small importance, the insertion of an additional bulkhead is not a vital matter. The result of the investigation showed that one additional bulkhead was required in the fore body in the 1915 Requirements compared with the 1932 Requirements, in order to obtain the same draught.

In a vessel of this type, a two-compartment, and, in some cases, a three-compartment vessel is fairly easy to obtain, due to the presence of oil fuel and fresh water tanks and the splitting up of engine rooms, auxiliary engine rooms and boiler rooms into separate compartments.

In the case of the mixed type of vessel between 450 ft. and 500 ft., in which the length of hold is the primary consideration, any relaxation in the Rules is immediately taken advantage of.

In the investigations previously mentioned a 450 ft. combined cargo and passenger liner was considered. This vessel had approximately the same permeabilities as Mr. Bryden has taken and the draught was taken which the vessel would have obtained under the 1932 Rules.

The design of this vessel gave two holds forward, two holds aft, and a combined engine and boiler room, giving a reasonable length of hold for the carriage of cargo both forward and aft, although it should be noted that there is one less bulkhead than the requirements of the Classification Rules.

On carrying out the same calculation for the 1915 Rules, it was found that an additional bulkhead was required in both the forward and aft cargo spaces, and, if the combined engine and boiler room had been 1 ft. longer, an additional bulkhead would have been required here also. It can be seen that the introduction of these two additional bulkheads would greatly diminish the usefulness of the spaces.

When the 1915 Regulations were adopted, too much attention was paid to the passenger type of vessel at the expense of the mixed type. The author makes the statement that it is doubtful if the relaxations permitted by the 1928 and 1932 Rules are justified. In the case of the mixed types, I think that it was absolutely necessary in order to keep this type of vessel in existence.

From the figures for the passenger type of vessel which Mr. Bryden has given on page 27, it will be seen that the factor of sub-division varies from ·376 to ·455 in conjunction with permeabilities which vary from 76 per cent. to 79 per cent. From a practical point of view, both these figures give a two-compartment standard, provided the cargo carried gives a permeability as calculated. The difference in the figures means that the first vessel will not sink so far in the water as the second in the event of damage causing a bulkhead to be carried away. In the case of the ·376 factor, there is a greater factor of safety if the actual permeability is different from the calculated permeability.

Taking the case of a vessel which, from the Rules, requires a two-compartment standard with a 70 per cent. permeability, this will be only a one-compartment ship with a reasonable factor of safety if the holds are empty and may approach the three-compartment standard if the cargo of low permeability is carried.

Considering the mixed type of vessel shown on page 26, in neither case, under the 1915 or 1932 Regulations, does it approach the two-compartment standard, so that if the vessel was hit on a bulkhead it would sink, with the number of bulkheads required under the old or new Rules, and yet under the 1915 Rules two more bulkheads are required than under the 1932 Regulations.

In conclusion I would like to ask Mr. Bryden two questions :—

1. When the freeboard disc coincides with the passenger line a fresh water allowance is incorporated in the disc. When the freeboard mark is well above the passenger line, is it left to the master of a passenger vessel to gauge the additional sinkage allowed in fresh water ?

2. On page 21 under the 1915 Regulations, he states that a watertight deck is not allowed below the level of the sub-division load line. Although this requirement appears to have lapsed, I would like to know if Mr. Bryden has any idea as to why it was introduced. Finally, it might be pointed out that if anyone has any doubts as to the efficiency of the sub-division on any ship in which he is travelling, I suggest that the best antidote is a perusal of Mr. Blocksidge's paper and he will probably be completely comforted by knowing that the last line of defence is of such a high standard.

REPLY BY THE AUTHOR.

On page 23 of the paper it was stated that under the 1928 regulations all side-scuttles having sills less than 6 inches above the deepest load line were to comply with Board of Trade Circular No. 1485 (under-water pattern side-lights), but, for the purpose of avoiding any possible misapprehension on the subject, I would add that although from the above it might appear that this Circular only came into force in 1928, it had actually been applicable to all vessels since 1909. It was, however, mentioned for the first time in sub-division regulations in 1928. It should also be noted that this Circular refers to side-lights of opening type, and is overuled by the sub-division regulations, in the case of side-lights situated in positions where the latter regulations do not permit the fitting of opening side-lights.

I am grateful to Mr. Buchanan, for his contribution, and particularly for that portion giving the the results of his investigations into the sub-division of the "mixed" and "passenger" types of ship in relation to fixed draughts. The requirement, in the case of a "mixed" type vessel of 450 feet under the 1915 Instructions, of two, or possibly even three more bulkheads than are required in the case for similar vessel under the 1932 Supplement, illustrates very clearly the essential difference between the degree of severity of the two sets of regulations. With regard to his question as to the fresh water allowance in the case of passenger ships, the sub-division regulations take no account of the nature of the water in which a ship floats, i.e., the statutory sub-division draught is the same whether the vessel is engaged in fresh or in salt water. It is understood, however, that Government officials in this country usually turn the blind eye if advantage is taken of a reasonable fresh water allowance when loading in fresh water before proceeding to the open sea, and the same thing occurs in Canada. The fitting of a watertight deck below the level of the sub-division load line was not permitted by the 1915 Instructions, owing to the detrimental effect upon the stability of a vessel if bilged wholly above the level of such a watertight deck.

Lloyd's Register Staff Association.

ANNUAL MEETING.

The Annual Business Meeting of the Staff Association was held in the London Office on Thursday, 26th March, 1936.

The President, Mr. E. W. Blocksidge, occupied the Chair.

Apologies for absence received from Dr. S. F. Dorey and Mr. W. Watt were intimated to the Meeting.

The Minutes of the previous Annual Meeting were read and adopted.

The Hon. Secretary then submitted the financial statement, and stated that in spite of the fact that an optiscope lantern and screen costing in all £17 15s. had been bought, the estimated balance on the year's working was £10 5s. 3d., compared with £15 1s. 9d. for the previous year. He stated that a sum of £10 5s. 6d. had been contributed by the London Members of the Association towards the cost of the optiscope, and that it had been decided to write off the remaining £7 9s. 6d., which accounted for the lower balance this year as compared with last year.

Mr. H. S. Newton said that he considered the Secretary's financial statement to be very satisfactory, and proposed that it should be adopted ; Mr. E. L. Knowles seconded the proposal.

Mr. Blocksidge : I am voicing the opinion of everyone, I feel sure, when I say we have had a very successful session, and before giving up the reins of office to-night I should like to say "Thank you" to all who have helped during my term as President. I appreciate greatly the assistance of the Past Presidents who have always been present at the Committee Meetings, and the members of the very strong Committee we had last year, who have given valuable support at all times. To many friends in the Office, not members of the Association, and to the Printing House and Messenger Staffs, I offer my best thanks.

I desire to express my appreciation for the hearty co-operation of my engineering colleagues shewn by their attendance at all the meetings during the past two years, even when the subjects were not of an engineering character. They have always been there in large numbers to support the activities of the Association, and I would like to appeal, on behalf of Mr. Ritchie, who, we hope, will take office next session, to you all to be at the meetings, even if the subjects are not of particular interest to you. Please, therefore, attend the meetings and take part in the discussion. The value of a paper is often spoiled by a slack discussion, and in fairness to the man who writes the paper, I appeal to all Members on the London Staff to come to the meetings, support the Chairman and contribute to the discussion.

It is a very old saying, and perfectly true in every phase of life—God only helps those who help themselves. If we do not look after ourselves as an Association, we cannot expect Lloyd's Register to look after us as an Association.

I would like, in closing, to say "Thank you one and all."

Mr. Blocksidge then intimated that the following provisional syllabus had been arranged for the 1936-37 Session :—

PROVISIONAL SYLLABUS.

1936.	
October 3	Special Lecture "The Development of Hull Form." J. F. C. Conn, Esq., B.Sc. (National Tank).
November 5	"Steering Gear." G. Buchanan.
December 3	"Hatchways." J. G. Buchanan.
1937.	
January 9	"Manufacture, Survey, and Testing of Electrical Equipment." G. O. Watson.
March 5	"Manufacture and Inspection of Seamless Tubes." G. T. Champness.

ELECTION OF OFFICE-BEARERS.

Mr. Blocksidge : The first item is the election of President. I have very much pleasure in proposing the name of Mr. G. D. Ritchie as our new President. This suggestion is a unanimous one, not only from the Outports, but from every member of the Committee and every member of the Association with whom we have been in touch.

Mr. Thomson in seconding the proposal said : "I am perfectly sure that, both from a personal and technical standpoint we are making a wise choice, and one which will reflect every credit on the Association.

Mr. Ritchie : I have looked up the precedents in this matter, and I find, according to the public records of the Association, that the newly-elected President was allowed to depart in peace without saying anything, but the warmth of your acceptance of this proposal urges me to say something.

I must say I feel slightly awed when I consider the brilliant men who have preceded me in this high office. It is not for me to live in the same world as Dr. Laws—a world of four, or is it five dimensions ! I cannot pretend to have that unique knowledge of the world, the flesh and the devil which is Mr. Chalmers. I may have, towards the end of the session, to apply to Mr. Blocksidge for some of his life-saving appliances—but I do thank you, gentlemen, very much for this great honour, and I look forward with confidence to a very successful session.

Mr. A. Urwin proposed and Mr. G. T. Thomas seconded a motion that Mr. J. M. Murray should be re-elected as Honorary Secretary to the Association. This motion was carried, and Mr. J. M. Murray agreed to continue in the position for the next session.

The London Members of the Committee were then elected as follows :—V. Lockney, J. G. Buchanan, A. Urwin, C. H. Stocks, G. Laing, R. J. L. Ward, L. H. F. Young, G. O. Watson.

Mr. Heck : Gentlemen, I rise to propose a vote of thanks and of congratulations to Mr. Blocksidge for the very excellent service he has rendered to us during the past two sessions as President. I feel that you will agree with me that Mr. Blocksidge has not only worked with enthusiasm, but he has worked with inspiration, and, as a result, the position of the Association, far from having weakened, has gained vastly in strength. In regard to the arrangement of papers, the contributions of papers, the arrangements of visits, and, shall I say, the settling of such small differences of opinion which have occurred on the Committee, Mr. Blocksidge has excelled. It is, therefore, with confidence that I ask you to join with me in according a very hearty vote of thanks, indeed, for his services.

Mr. Blocksidge : I thank Mr. Heck for his words of appreciation.